Article

Preferences for Alternative Fuel Trucks among International Transport Companies

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Abstract: Fossil-fuel consumption in land freight is over 19%. Alternative fuel trucks (AFTs) help decrease greenhouse gas emissions. However, AFT preferences in international land transit have received little attention due to passing through various countries with different financial and regulation plans. This variety affects AFTs' market share. This study analyzes factors influencing AFT preferences in international land transit. A questionnaire (designed in four sections) was distributed among international transport companies in Iran and Europe. A principal component analysis helped extract principal components composed of cognitive, environmental, policy, practical, and economic variables. The multinomial logit models include 26 meaningful variables. The marginal effect analysis shows that the service quality of the manufacturer, importance of greenhouse gas mitigation, and social responsibility do not significantly elevate AFT preferences. In addition, cargo type influences AFT choice. The results of this study help to identify the barriers affecting AFTs' market share, which can positively impact air pollution.

Keywords: alternative fuel; greenhouse gas emissions; heavy-duty truck; international land freight; multinomial logit model; principal component analysis

1. Introduction

The six most impactful greenhouse gases (GHG) are carbon dioxide (CO_2), methane, nitrous oxide, hydrofluorocarbons, per-fluorocarbons, and sulfur hexafluoride [1]. CO_2 stands out as the predominant GHG emitted [2], with a record of 36,153 million tons in 2017 [3]. The transport sector, surpassing the passenger sector [1,2], is the primary contributor to CO_2 emissions [4]. Within freight transport, road freight transport plays a vital role in facilitating other freight transportation modes (such as sea, air, and rail) and carrying heavy-duty cargoes [5]. Projections indicate that if energy consumption rises by 75%, CO_2 emissions from freight transport will double by 2050. To effectively reduce direct CO_2 emissions, a viable approach is to replace fossil fuels with alternative fuel truck (AFT) options, such as compressed natural gas (CNG), liquefied natural gas (LNG), battery electric (BE), hydrogen, and biogas [6].

The European Parliament has set a target to increase the market shares of alternative fuels, specifically AFTs, by 14% by 2030. Additionally, Europe aims at reducing CO_2 emissions of the road fleet by up to 90% by 2050 [7]. This has spurred various initiatives, including Norway's plan to replace 50% of trucks with AFTs by 2030 [6], Sweden's ambition to achieve a 70% reduction in GHG emissions in domestic land transit by 2030 [8], and Germany's consideration of a 40% GHG emission reduction within the transport sector [1]. Norway, for instance, has set a target to replace all light vans with zero-emission vehicles

by 2025, with new vans and 50% of new heavy good vehicles running on electricity or hydrogen by 2030 [5]. Leading truck manufacturers are also actively developing eco-friendly innovations, such as Tesla's Battery Electric Trucks (BETs) with an average driving range of 800 km [9]; the analysis of Fuel-Cell Electric Trucks by Toyota, Kenworth, and Nikola Motor [10]; and ongoing research on hybrid trucks by Scania and Volvo [11,12]. However, despite these efforts, the market shares of AFTs have not witnessed significant growth [6]. In Europe, the majority of the road fleet still consists of 361,135 registered new diesel trucks, with only 357 new BETs enlisted in 2019. Sweden's road fleet comprises 95% Diesel Trucks, 5% biogas trucks, and a mere 2% BETs. Furthermore, alternatively fueled trucks account for only 0.05% of the total in Germany [13].

To foster broader acceptance of alternative fuel trucks (AFTs) and address the challenges faced by international transport companies (ITCs) in transitioning from conventional fuel trucks to AFTs, it is essential to implement necessary regulations and overcome existing barriers. A further analysis is required to examine the cognitive, economic, environmental, policy, and practical factors that influence the choice of AFTs among ITCs, as well as the considerations related to AFT adoption in land freight. Discussions covered in previous studies, future study suggestions, and the innovations of the current study are as follows:

1. Previous studies mainly have analyzed the AFT choice in domestic land transit over international land transit (more details are available in Table A1, Appendix A). Analyzing the AFT choice in international land transit is necessary since it includes different countries en route with varying financial conditions, policies, regulations, and incentive plans that may be barriers to AFT market shares in international land transit [14]. In addition, an analysis of international transport routes is needed to plan for AFT use [15,16]. To cover the mentioned literature gaps, the Europe–Iran international transit route is chosen for this study.

2. An acceptance analysis of AFTs in ITCs is among the suggestions for future studies [15]. European and Iranian ITCs are therefore chosen for this study.

3. Applying Stated Preference method for AFT adoption was also suggested for further research [15]. This approach is therefore used in this study. A questionnaire was distributed online among international transport companies. It is assumed that governmental and incentive policies mentioned in the questionnaire are applied during the survey. Details of these governmental and incentive policies are available in Table A2. The questionnaire was distributed to gather data on their background information; their alternative fuel choice; their level of agreement with cognitive, environmental, and policy factors; and the importance degree of practical, economic, and some other policy factors in adopting alternative fuel trucks.

4. Regarding alternative fuel truck preferences, not all alternative fuels have been analyzed in previous studies altogether. As far as we know, preferences of BETs, CNG trucks, LNG trucks, and hydrogen trucks (a hydrogen-fueled truck includes hydrogen space rockets and uses hydrogen as fuel; the chemical energy of hydrogen is converted to mechanical energy in these trucks [17]) have been previously evaluated in Germany [14]. Adding an analysis of biogas truck preferences in this study on top of preferences regarding CNG trucks, LNG trucks, BETs, hydrogen trucks, and biogas trucks are analyzed in the Europe–Iran international transport route.

5. Previous studies have applied cognitive, environmental, policy, practical, and economic variables via various methods (such as a factor analysis, logistic regression model, Delphi method, and mixed logit) to analyze alternative fuel cars and trucks (details are available in Table A1 in Appendix A) in urban commuting and domestic land transit. The effect of cognitive, environmental, policy, practical, and economic variables on AFT choices in international land transit is tackled in this study.

Drawing upon prior research, the present study aims at testing the hypothesis that cognitive, environmental, policy, practical, economic factors, and cargo type impact the decision-making process concerning alternative fuel trucks (AFTs) in international land

transit. To examine the validity of this hypothesis, a principal component analysis and multinomial logit models are utilized as analytical tools.

In addition to analyzing European and Iranian ITCs' AFT preferences, answers to the questions below are investigated:

1. Based on AFT specifications, which AFT will ITCs prefer?
2. Which cognitive, environmental, economic, policy, and practical factors motivate ITCs to choose AFTs?

The results of this study will help to identify cognitive, economic, environmental, policy, and practical barriers affecting AFT choice. Providing solutions to overcome such barriers will help the faster adoption of AFTs in international land transit. This study also helps to identify effective regulations and policies that help increase the market shares of AFTs.

In Appendix B, Table A2 provides references of analyzed factors collected from previous studies.

2. Literature Review

According to the transport analysis report in 2020, transportation contributes to 20% of global greenhouse gas (GHG) emissions. However, certain countries, such as Norway [6] and Sweden [18], experience even higher percentages, with 30% and 33.3% of emissions, respectively, attributed to the transport sector. It is evident that transportation is one of the leading sectors in terms of GHG emissions worldwide [14]. Consequently, the widespread adoption of alternative fuel trucks (AFTs) is widely regarded as a primary approach to mitigate the environmental impact caused by transportation [19].

The analysis of alternative fuel diffusion has been prompted by the increasing demand for international land transit [20] along with the high greenhouse gas (GHG) emissions and environmental concerns associated with traditional transportation methods [16]. However, international transport companies (ITCs) face multiple barriers that hinder their adoption of alternative fuel trucks (AFTs) [6]. These barriers include economic, technical, bureaucratic, general perspective, legal, and physical factors as well as unwanted policy consequences [6]. Additionally, two recently identified barriers include institutional factors related to market shares, required infrastructure, economic challenges, inadequate interaction, and supply issues, as well as functional factors involving acceptance and attitudinal issues [21]. Previous studies have summarized the challenges of alternative fuel diffusion into five categories: financial, environmental, political, functional, and social (Figure 1).

Financial issues, such as ownership cost, significantly affect investments in alternative fuel technologies [22]. The diverse cost components, including purchase price, fuel price, registration fee, maintenance costs, and insurance fees, coupled with complex import tariffs result in varying calculations of ownership costs [23]. Contrary to [1], Ref. [8] demonstrate that the ownership cost of diesel trucks is lower than that of BETs and CNG trucks. Several suggested solutions to enhance investment in AFT technology include the improvement of AFT technology itself [24], reduced import tariffs and tolls for AFT users, and the implementation of a CO_2 budget and tax mechanisms to facilitate the development of infrastructure and low-priced alternative fuels [25].

The analysis of alternative fuel trucks (AFTs), including BETs, biogas trucks, and hybrid trucks, has been driven by environmental concerns to mitigate greenhouse gas (GHG) emissions [26]. Various approaches, such as generating electric power from nuclear energy [27] and utilizing BETs [28], have been explored to address GHG emissions. A Monte Carlo Simulation conducted by [13] reveals that a BET has 80% fewer GHG emissions compared to biogas trucks, contrary to the findings of [29]. However, the usage of BETs has shown adverse effects on certain countries despite their technological efficiency and low GHG emissions [19]. A macro-level analysis of practical variables has indicated that the ecosystem of the United Arab Emirates is unsuitable for electric vehicles [29].
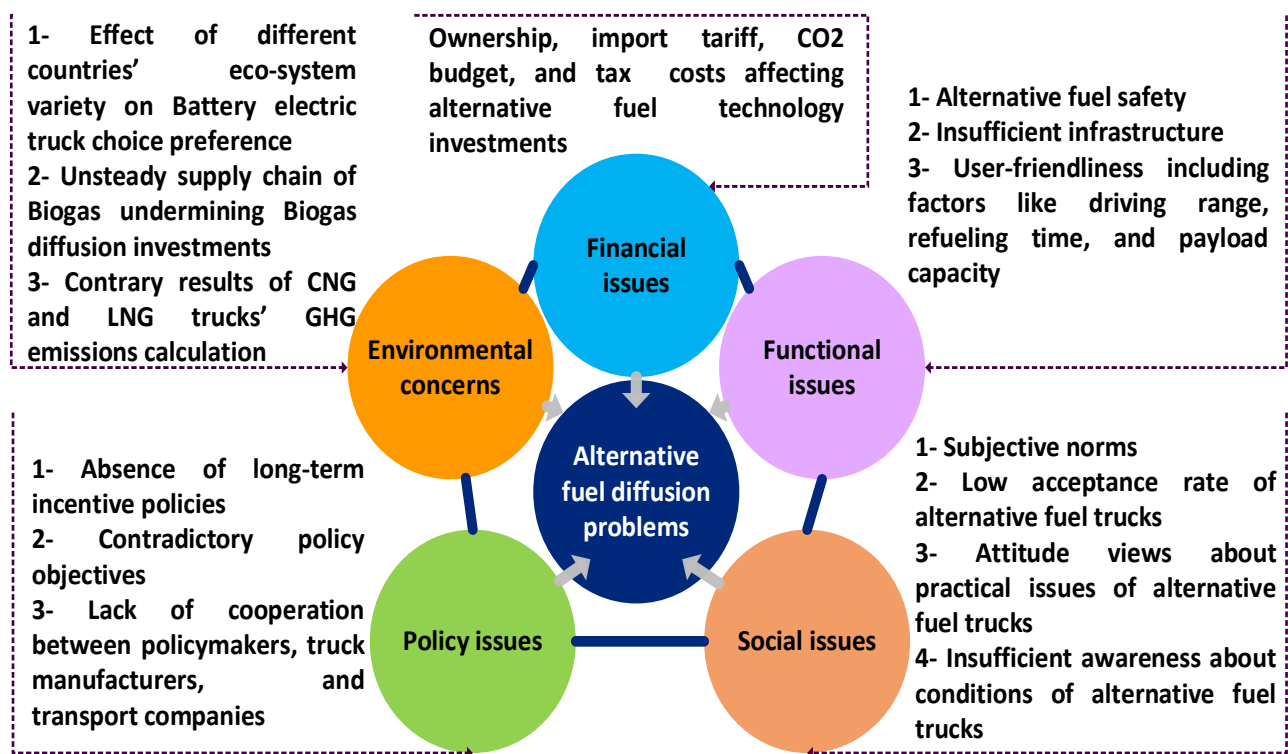
1- Effect of different countries' eco-system variety on Battery electric truck choice preference
2- Unsteady supply chain of Biogas undermining Biogas diffusion investments
3- Contrary results of CNG and LNG trucks' GHG emissions calculation

Ownership, import tariff, CO2 budget, and tax costs affecting alternative fuel technology investments

1- Alternative fuel safety
2- Insufficient infrastructure
3- User-friendliness including factors like driving range, refueling time, and payload capacity

Environmental concerns

Financial issues

Functional issues

Alternative fuel diffusion problems

1- Absence of long-term incentive policies
2- Contradictory policy objectives
3- Lack of cooperation between policymakers, truck manufacturers, and transport companies

Policy issues

Social issues

1- Subjective norms
2- Low acceptance rate of alternative fuel trucks
3- Attitude views about practical issues of alternative fuel trucks
4- Insufficient awareness about conditions of alternative fuel trucks

Figure 1. Literature review summarization.

Conflicting results have been found regarding the classification of CNG, LNG, and bio-methane as biogas due to their similar supply chains [26]. While Refs. [29,30] suggest that CNG-dependent technologies emit 33% more greenhouse gases and highlight the long-lasting drawbacks of this technology, Refs. [1,25] find that bio-methane and CNG have lower GHG emissions.

Policy issues also significantly impact the market shares of AFTs, with the absence of long-term policies [31] and conflicting political benefits and objectives [32] being key factors. Several suggestions have been proposed to increase the market shares of AFTs, including publicizing the economic and environmental benefits of CO_2 tax [32], providing necessary infrastructure [33,34], implementing long-term incentive policies [5], and fostering collaboration among policymakers, ITCs, and AFT manufacturers [35].

Functionality issues are also crucial for companies when considering the adoption of AFTs. While improved safety encourages ITCs to choose AFTs, inadequate infrastructure poses a significant barrier [36]. Market share considerations for BETs are influenced by factors such as performance on long-haul routes [37], user-friendliness [38], driving range on long-haul routes, required recharging duration [39], acceleration, fleet size, and payload capacity [39]. The limited market shares of hydrogen trucks can be attributed to the suitability of hydrogen fuel for heat and electricity production [26].

Social issues also play a role in determining the market shares of AFTs, including subjective norms (the importance of people's approval of specific behaviors), peer pressure to care for the environment [40], low acceptance rates of AFTs [41], and attitude problems regarding the practical issues of AFTs [42]. Raising awareness about current environmental conditions and addressing practical issues related to AFTs are suggested to increase their acceptance rate [43].

In summary, diesel trucks still dominate the market shares compared to AFTs, necessitating efforts to reduce GHG emissions [13]. However, increasing the market shares of AFTs and modeling the truck choice behavior of ITCs is a complex task due to the diverse and sometimes conflicting factors, including environmental, financial, functional, social, and policy issues. Furthermore, there has been limited attention given to international land

transit, which has distinct characteristics from domestic land transit [14]. Therefore, it is recommended to conduct an AFT choice analysis in international land transit [14,15,43] and examine the acceptance of AFTs among ITCs [15]. For the purposes of the current study, the Europe–Iran transit route has been selected to model the AFT choice behavior of international transport companies (ITC).

3. Materials and Methods

3.1. Data Collection

The link of the online questionnaire was distributed among ITCs in Iran and Europe by email. The questionnaire was distributed among 684 international transport companies in 20 countries to gather data on their background information; their alternative fuel choice; their level of agreement with cognitive, environmental, and policy factors; and the importance degree of practical, economic, and some other policy factors in adopting alternative fuel trucks. The ITCs were chosen from the members of international freight forwarding websites (World Cargo Alliance (WCA) and JC Trans). Among the list of the members, the email addresses of the ITCs providing international land transit were collected. Two versions of the questionnaire were designed (Persian for Iranian ITCs and English for European ITCs). The content validity of the questionnaire was determined by reviewing previous related studies. The translation consistencies were checked by Persian and English expert editors. Furthermore, the questionnaire was fine-tuned by a pilot study. Sample size can be calculated by Cochran's formula, which for this study, minimum of 384 ITCs were calculated. The fine-tuned online questionnaire was distributed among 30 countries (29 European countries and Iran), and 684 ITCs across 20 countries participated in the survey. ITCs from European countries taking part in the survey are as follows: Germany, France, Czech Republic, Spain, Belgium, Sweden, Italy, Netherlands, Poland, Denmark, Portugal, Swiss, Estonia, Greece, Lithuania, Finland, Austria, Norway, and Slovakia.

3.2. Mathematical Methods

The following mathematical methods were used in this study. The third and the fourth parts of the questionnaire included 16 Likert scale variables (listed in Table A2 in the Appendix B). The testing result showed these variables were highly correlated. Thus, to reduce dimensions of data and obtain non-correlated variables, principal component analysis (PCA) was applied. By applying PCA, these Likert scale variables were reduced to eleven independent principal components (PC), and unimportant variables not associated with AFT choice were screened out. These formed PCs, as new linear combination, included the Likert scale variables with maximum data variance. In addition, multinomial logit model (MNL) was appropriate for modeling transport mode choice. Since the collected data for mode choices was categorical, the MNL model was a reliable method [44,45]. Thus, two MNL models with a confidence level of 90% uncovered the variables explaining future AFT choice behavior. Company characteristics were independent variables in both models. In the first model, Likert scale variables and, in the second model, PCs were the independent variables. Fifteen variables in the first model and eleven variables in the second model became significant ($p < 0.10$). Lastly, the results of both models were compared to each other. Steps of the current study are also described in Figures 2 and A1 in Appendix C.
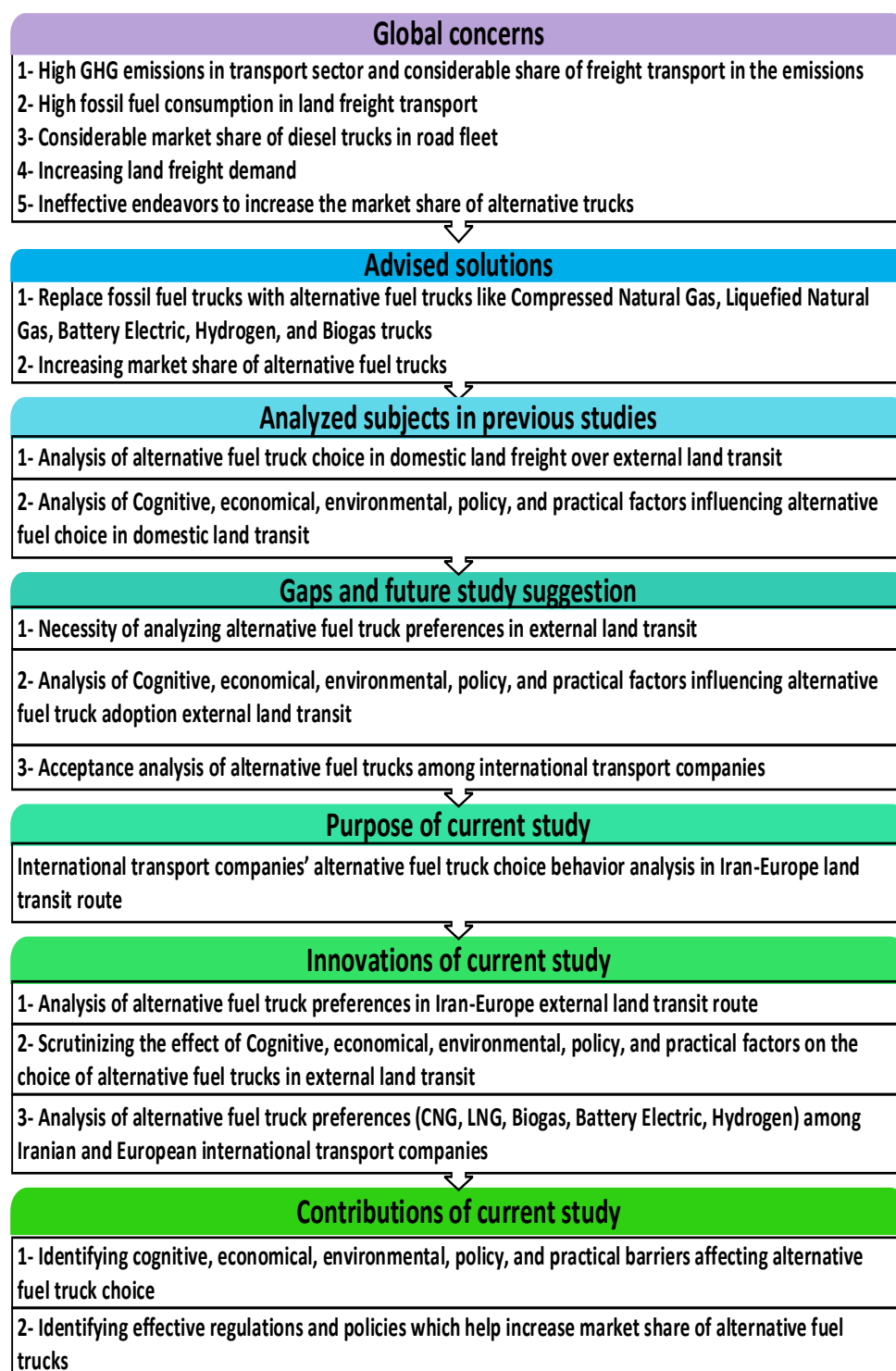
Global concerns

1- High GHG emissions in transport sector and considerable share of freight transport in the emissions

2- High fossil fuel consumption in land freight transport

3- Considerable market share of diesel trucks in road fleet

4- Increasing land freight demand

5- Ineffective endeavors to increase the market share of alternative trucks

Advised solutions

1- Replace fossil fuel trucks with alternative fuel trucks like Compressed Natural Gas, Liquefied Natural Gas, Battery Electric, Hydrogen, and Biogas trucks

2- Increasing market share of alternative fuel trucks

Analyzed subjects in previous studies

1- Analysis of alternative fuel truck choice in domestic land freight over external land transit

2- Analysis of Cognitive, economical, environmental, policy, and practical factors influencing alternative fuel choice in domestic land transit

Gaps and future study suggestion

1- Necessity of analyzing alternative fuel truck preferences in external land transit

2- Analysis of Cognitive, economical, environmental, policy, and practical factors influencing alternative fuel truck adoption external land transit

3- Acceptance analysis of alternative fuel trucks among international transport companies

Purpose of current study

International transport companies' alternative fuel truck choice behavior analysis in Iran-Europe land transit route

Innovations of current study

1- Analysis of alternative fuel truck preferences in Iran-Europe external land transit route

2- Scrutinizing the effect of Cognitive, economical, environmental, policy, and practical factors on the choice of alternative fuel trucks in external land transit

3- Analysis of alternative fuel truck preferences (CNG, LNG, Biogas, Battery Electric, Hydrogen) among Iranian and European international transport companies

Contributions of current study

1- Identifying cognitive, economical, environmental, policy, and practical barriers affecting alternative fuel truck choice

2- Identifying effective regulations and policies which help increase market share of alternative fuel trucks

Figure 2. Conceptual framework, innovations, and contributions of the current study.

3.2.1. Principal Component Analysis

PCA is a broadly used dimensional-reduction method for high dimensional and correlated data. By applying PCA, non-correlated linear combinations of original variables called PCs are formed. PCs are the new sets of orthogonal axes counting for the maximum data variance [46]. Thus, $PC1$ is the new linear combination of actual variables (x_N) [46]:

$$PC1 = \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_N x_N \tag{1}$$

The loading showed the correlation between actual variables and PCs. In addition, the significance degree of actual variables was indicated in the loading. The higher loading indicated the higher importance level of the original variable in the obtained PC. Another formula to calculate the loading was as follows:

$$L_{ij} = w_{ij}/\hat{s}_j(\sqrt{\lambda_i}) \tag{2}$$

In the above formula, the loading of jth variable in ith PC was indicated in L_{ij}. The jth variable' weight was shown as w_{ij}, eigenvalue (data variance explained by PC) as λ_i, and standard deviation of jth variable as $\hat{s}_j$.

3.2.2. Multinomial Logit Model

Conventional discrete choice models, centered on random utility theory, have been proposed for mode choice probability estimation [47]. Based on the random utility theory, company n selects the AFT from the choice set with the most prominent utility. Each utility u_{jn} contains one or more choices. Thus, with V_{jn} describing AFTs' observed attributes, and ε_{jn} as error term marking unobserved attributes of AFT, the utility function of each company is as follows:

$$u_{jn} = V_{jn} + \varepsilon_{jn} \tag{3}$$

In addition, linear function's most common utility form is as follows:

$$V_{jn} = \beta_{1jn}x_{1jn} + \ldots + \beta_{kjn}x_{kjn}, \tag{4}$$

where $(\beta_{1jn}, \ldots, \beta_{kjn})$ weighting parameters describe $(x_{1jn}, \ldots, x_{kjn})$ independent variables' marginal utility. Consequently, company n chooses AFT j with the probability of the following:

$$p_n(j|C_n) = pr(u_{jn} > u_{in}; \forall i \in C_n) \tag{5}$$

The multinomial logit model (MNL) is a derivative of the ε_{jn} distribution and is appropriate for mode choice behavior prediction. Yielding to Gumbel distribution ε_{jn} has independent and identical distribution in the MNL model [48]. Thus, pursuing to forecast AFT choice probability via MNL model following function is advised:

$$P_n(j|C_n) = e^{v_{jn}}/\Sigma_{n \in C_n}e^{v_{jn}} \tag{6}$$

In the above function, j illustrates the considered AFT for which choice probability is calculated. While an increase in systematic utility of each AFT causes an increase in choice probability of that AFT, an increase in systematic utility of other AFTs decreases the choice probability of considered AFT.

After generating the model, elasticity calculates choice probability changes in response to a one percent increase of an independent variable. The marginal effect also measures the choice probability changes with one unit increase of the independent variable [48].

Furthermore, the aggregate proportion of correct prediction calculates the model's overall correct prediction and affirms models' validity subject to the equivalence between the estimated value and the chosen actual alternative. Dividing the correct prediction summation of the alternatives (offered in the contingency table) by the total selections made determines it [48].

3.3. Questionnaire Description

The questionnaire included four parts. The background information (such as the country of registration, the number of the owned trucks, and the previous experience with AFT) was collected in the first section. Offering AFT details in the second section, ITCs' views about the alternative fuel choice and main problems of AFTs were collected. ITCs announced their level of agreement with cognitive, environmental, and policy factors using a five-point Likert scale (from 1 = completely disagree to 5 = completely agree) in

the third section. In the fourth section, ITCs specified the importance level of practical, economic, and other policy factors in choosing AFTs using a five-point Likert scale (from 1 = completely unimportant to 5 = completely important). Details of the questionnaire references are represented in Table A2 in the Appendix B.

3.4. Descriptive Statistics

An amount of 684 ITCs from 20 countries took part in the survey. All ITCs had carried dangerous cargo, general cargo, bulk cargo, liquefied bulk cargo, containerized cargo, passenger cargo, project cargo, refrigerated cargo, roll-on/roll-off, and perishable cargo.

From the 38,130 enlisted trucks, 68.7% ran on diesel, 29.0% on CNG, 1.8% on BE, and 0.5% on LNG. While the Iranian ITCs filling the questionnaire had diesel trucks, 146 European ITCs had previous experience with BETs. In addition, ITCs chose the average driving range as the main problem of CNG trucks and BETs, GHG emissions for LNG trucks, and tank capacity for biogas trucks and hydrogen trucks. Lastly, in answer to choosing alternative fuels, 16% of ITCs chose CNG, 23% BE, 14% biogas, 5% LNG, 4% hydrogen, and 3% chose none of the fuels mentioned.

4. Principal Component Analysis Result

By applying PCA to the 16 Likert scale variables and on the standardized data (using Stata 17 software), eleven PCs with 73% cumulative variance were extracted. The PCs with eigenvalues greater than one were kept [46]. Table 1 shows the results of the PC extractions, and Table 2 shows the variable composition of each PC. The loadings in Table 2 show the correlation between actual variables and PCs. In addition, the significance degree of actual variables is indicated in the loading. The higher loading indicates the higher importance level of the actual variable in the obtained PC [46].

Table 1. Extracted PCs and their proportion of variance.

PC	Eigenvalue	Proportion of Variance (%)	Cumulative Variance (%)
1	9.586	18.80	18.80
2	6.956	13.64	32.44
3	4.722	9.26	41.70
4	4.536	8.90	50.59
5	2.647	5.19	55.78
6	2.314	4.54	60.32
7	1.866	3.66	63.98
8	1.554	3.05	67.03
9	1.117	2.19	69.22
10	1.049	2.06	71.28
11	1.008	1.87	73.15

Table 2. Loadings of original variables in PCs.

Principal Component	Variable	Loading
	Practical variables	
	Refueling time	0.278
	Maximum driving range	0.257
	Refueling safety	0.259
	The maximum payload capacity of AFT	0.267
	AFT engine power in different road conditions	0.257
	Vehicle size and loading space dimensions	0.261
PC1	Service quality of the manufacturer	0.260
	Availability of alternative fuel station	0.257
	Manufacturer's guaranty and warranty	0.265
	Availability of alternative fuels in the petrol station	0.258
	Driver comfortability	0.257
	Familiarity with technical issues of AFT and new technologies	0.258
	Availability of auto repair for AFT	0.260
	AFT acceleration time	0.282

Table 2. *Cont.*

Principal Component	Variable	Loading
	Policy variables	
	Discount in custom tax and duty charges in case of using AFT will affect my decision.	0.318
	Alternative fuel pricing policies will affect my decision.	0.316
	Companies tax exemption in case of using AFT	0.301
	Granting privilege in finishing custom formalities in case of using AFT	0.310
PC2	Discount in liability insurance in case of using AFT	0.307
	Effect of entering low-emission zones on AFT purchase	0.305
	Financial incentives when purchasing/operating an AFT	0.303
	Environmental agreements to decrease pollution	0.309
	Effect of government loans with no or low interest rate to help to buy AFT	0.306
	Environmental variables	
	The low GHG emission of trucks is important for me.	−0.349
	The low noise pollution of trucks is important for me.	−0.359
PC3	The environmental effects of AFT manufacturing will affect my decision.	−0.357
	The well-to-tank GHG emission will affect my decision.	−0.350
	The tank-to-wheel GHG emission will affect my decision.	−0.347
	Cognitive variables	
	The brand and model of the truck is important for me.	0.278
	Colleague's advice about AFT will affect my decision.	0.218
	In the case of globalization, I will use AFT.	0.245
	AFT top speed is important for me.	0.262
	By using AFT and new technology, I will be proud.	0.257
PC4	By using AFT and new technology, I will have self-confidence.	0.247
	By using AFT, I will feel superior.	0.260
	I would like to be a leader in environmentally friendly technologies.	0.254
	I cannot rely on AFT and new technology.	0.262
	I would like to be part of socially responsible activities.	0.264
	I am excited about new technologies and innovations.	0.225
	Economic variables	
	Alternative fuel cost	0.529
PC5	Maintenance costs of AFT (tax, duty, & insurance)	0.505
	Service costs of AFT	0.525
	AFT purchase cost	0.341
	Colleague's advice about AFT will affect my decision.	0.16
	By using AFT and new technology, I will be proud.	0.437
PC6	I am excited about new technologies and innovations.	0.161
	Environmental agreements, such as Paris Agreement, are necessary to decrease GHG emissions in land transportation.	−0.284
	Effect of entering low-noise zones on AFT purchase	−0.255
	The environmental effects of AFT manufacturing will affect my decision.	0.206
	The tank-to-wheel GHG emission will affect my decision.	0.217
PC7	Truck weight	0.472
	Cabin design (ease of accessibility)	0.47
	Holding training courses for repairing and maintenance AFT	0.462
PC8	Environmental agreements, such as Paris Agreement, are necessary to decrease GHG emissions in land transportation.	0.577
	Effect of entering low-noise zones on AFT purchase	0.608
	AFT has the required performance.	0.718
PC9	The environmental effects of recycling AFT parts will affect my decision.	−0.466
	Second-hand AFT sale value	0.339
PC10	The environmental effects of recycling AFT parts will affect my decision.	0.476
	Second-hand AFT sale value	0.815
	AFT has the required performance.	0.481
PC11	The environmental effects of recycling AFT parts will affect my decision.	0.657
	AFT purchase cost	−0.303
	Second-hand AFT sale value	−0.312

PC1 is composed of practical variables of AFTs, PC2 of policy variables, PC3 of environmental variables, PC4 of cognitive variables, and PC5 of economic variables. The details of PC6, PC7, PC8, PC9, PC10, and PC11 are also available in Table 2.

5. Multinomial Logit Model Result Analysis and Discussion

The calibration of the first model with Likert scale variables is demonstrated in Table 3 and the calibration of the second model with PCs in Table 4. All the variables in both models are significant at a 90% level. Three alternatives are defined in each model. CNG and LNG trucks are the dependent variables in the first alternative, BETs in the second alternative, and hydrogen and biogas trucks in the third alternative. ITCs choosing none of the alternative fuels are not included in the models. The first and the third alternatives include two homogenized choices. Consequently, each alternative has a minimum share of 15%.

Table 3. MNL model calibration with Likert scale variables.

Variable	Model with Likert Scale Variables					
	CNG and LNG Trucks (C1)		BET (C2)		Hydrogen and Biogas Trucks (C3)	
	Coef.	*t*-Test	Coef.	*t*-Test	Coef.	*t*-Test
Dummy						
Dangerous cargo	−0.392 ***	−2.38				
Bulk cargo	0.407 **	2.16				
Liquefied bulk cargo	0.375 **	2.29				
Containerized cargo	0.488 ***	2.98				
Roll-On/Roll-Off cargo					0.467 **	2.27
The battery capacity of BET			0.4 *	1.92		
Refueling time of biogas trucks					0.557 **	2.56
Numerical						
Number of owned CNG trucks			−0.199 **	−2.59		
Likert scale (ordinal)						
Tank-to-wheel GHG emissions will affect my decision.	0.137 *	1.89				
Low noise pollution of trucks is important for me.	0.212 **	2.23				
AFT top speed is important for me.			0.508 ***	2.97		
I would like to be part of socially responsible activities.			−0.322 **	−2.05		
Alternative fuel pricing policies will affect my decision.					−0.265 **	−2.54
Degree of the effectiveness of "Service quality of manufacturer" on AFT choice					−0.146 **	−2.08
Degree of the effectiveness of "Maintenance costs of AFT" on AFT choice					0.359 ***	3.5

Note: ***, **, * → Significance at 1%, 5%, 10% level.

Based on Table 5, the variables are non-zero in both models because $[-2(\text{LL}(0) - \text{LL}(\beta))]$ is greater than the critical value. In addition, in both models, $[-2(\text{LL}(C) - \text{LL}(\beta))]$ is greater than the critical value emphasizing that the final models are better than the models with only constant variables. Further, the matching aggregate proportion of correct prediction value with the highest chosen alternative approves both models' validity [48].

Table 4. MNL model calibration with principal components.

| Variable | Model with Principal Components | | | | | |
| | CNG and LNG Trucks (C1) | | BET (C2) | | Hydrogen and Biogas Trucks (C3) | |
	Coef.	*t*-Test	Coef.	*t*-Test	Coef.	*t*-Test
Dummy						
Dangerous cargo			0.297 *	1.69		
Bulk cargo	0.699 ***	3.93				
Liquefied bulk cargo			−0.498 ***	−2.78		
Containerized cargo	0.429 **	2.42				
Refueling time of biogas trucks					0.881 *	1.93
Constant						
C0					−5.45 ***	−6
Principal components (continuous)						
PC2 (Policy variables)	0.069 *	1.84				
PC1 (Practical variables)	1.909 ***	8.66	1.668 ***	7.62		
PC3 (Environmental variables)			−0.123 ***	−2.65		
PC7					−0.335 ***	−2.86
PC11						−3.46

Note: ***, **, * → Significance at 1%, 5%, 10% level.

Table 5. MNL model estimations.

	Model with Likert Scale Variables	Model with PCs
Number of observations	657	657
LL(0)	−721.788	−721.788
LL(C)	−641.781	−641.781
LL(β)	−605.303	−375.907
ρ^2	0.161	0.479
ρ_c^2	0.056	0.414
ρ_{ADJ}^2	0.045	0.408
Critical value with confidence level of 0.1	22.31	17.28
−2(LL(0) − LL(β))	232.97	691.762
−2(LL(C) − LL(β))	72.956	531.748
Degree of freedom	642	645
Aggregate proportion of correct prediction	45%	64%

In addition, the goodness of fit, the aggregate proportion of correct prediction, and R-square value signify the superior model. Comparing the ρ^2 value of different models generated from the same data set with the same alternatives helps find the superior model. The higher value confirms the model's superiority [48]. Thus, the model with PCs emphasizes its superiority due to the higher correct prediction and ρ^2 value.

5.1. MNL Model Results with Likert Scale Variables

The results of MNL model calibration with Likert scale variables, their marginal effect, and consistency with previous studies are discussed in this section. Fifteen variables, including seven Likert scale variables, are significant in the model. These Likert scale

variables measure ITCs' level of agreement with the below statements (ranging from 1 = completely disagree to 5 = completely agree):

1. Effect of tank-to-wheel GHG emissions on AFT choice;
2. Importance of low noise pollution on AFT choice;
3. Importance of AFT top speed on AFT choice;
4. Being part of socially responsible activities;
5. Effect of alternative fuels pricing policies on AFT choice;
6. Effectiveness of service quality of the manufacturer on AFT choice;
7. Effectiveness of maintenance costs on AFT choice.

The direct marginal effect of choice alternatives is calculated by applying five scenarios to these Likert scale variables. In each defined *i*th scenario, it is assumed all ITCs have chosen *i*th Likert scale value (*i* = 1, 2, 3, 4, 5). For example, in the first scenario, all ITCs are assumed to have chosen Likert scale value 1 (Figure 3). In fact, it is supposed that all ITCs completely disagree with the effectiveness of tank-to-wheel GHG emissions on the AFT choice, and direct marginal effect-of-choice alternatives are calculated. Direct marginal effect is also calculated by assuming all ITCs completely disagree with the effectiveness and importance of low noise pollution, AFT top speed, being socially responsible, alternative fuel pricing, service quality of the manufacturer, and maintenance costs. Accordingly, the direct marginal effect is calculated in the second, third, fourth, and fifth scenario as well. Likert scale value 2 (disagree) in the second scenario, 3 (undecided) in the third scenario, 4 (agree) in the fourth scenario, and 5 (completely agree) in the fifth scenario are supposed to be chosen by all ITCs.

Figure 3. Direct marginal effect of Likert scale variables.

Regarding CNG and LNG trucks, the importance of *tank-to-wheel GHG emissions* does not help increasing the choice probability of emission-free trucks; ITCs still prefer to choose CNG and LNG trucks. This finding is also consistent with previous studies, which find other variables (such as maintenance costs) are more important for ITCs. In fact, it is stated that GHG emission reduction is not their first priority [24,36,49]. In addition, the particular analysis of tank-to-wheel GHG emissions is considered insufficient. In addition, ITCs consider other factors in choosing their preferred fuel. Well-to-wheel GHG emissions analysis is suggested instead [50].

Furthermore, the *low noise pollution* of the BETs, CNG and LNG trucks does not appear to be a criteria of choice according to the results. Based on previous studies, *low noise pollution* is a characteristic of BETs; however, they are still less preferred due to insufficient driving range [51,52]. In addition, if implemented plans do not fully address the economic and political issues faced by ITCs, the current regulations and environmental concerns cannot elevate the market shares of BETs [53,54]. In addition, choice shares of CNG and LNG trucks increase by 19% even if all ITCs agree that *low noise pollution* is completely important (Figure 3).

Concerning BETs, the result of the MNL model in this study showed that the AFT *top speed* is positively associated with BET choice. Analyzing previous studies, considerable ratio sensitivity to the *top speed* of BETs is also obtained in the cost minimization models. Indeed electric vehicles preferred velocity is among the key parameters affecting logistics planning [39].

However, ITCs do not prefer to choose BETs and *be a part of socially responsible activities*. Liability issues and cost minimization are predominant concerns of ITCs. If ITCs' underlying concerns (such as economic issues) are not addressed, ITCs are not encouraged to choose BETs out of feeling responsible to society and the environment [36,49]. Moreover, having experience with CNG trucks negatively affects BETs' market share, which has also been discussed by other researchers [25].

Direct association between BET choice and *battery capacity* is found in this study via an MNL model indicating a drawback of BETs, which is in accordance with the literature [36,50]. Hence, if the battery technology and driving range improve, BET choice will increase [14].

Analyzing choice share of hydrogen and biogas trucks, *alternative fuel pricing policy* negatively affects ITCs' choice preference. Impractical and short-term *pricing policies* are found to have hindering effect on the market shares of hydrogen and biogas trucks in previous studies as well [31,39,51]. In addition, choice share of hydrogen and biogas trucks decreases by 18%, even if all ITCs agree that alternative fuel pricing policies affect their AFT choice preference (Figure 3).

The *service quality of the manufacturers* is another barrier preventing ITCs from choosing hydrogen and biogas trucks. Moreover, the conducted scenarios resulted in a 9% decrease in the choice of this alternative (Figure 3). Technology issues have been considered as main issues in previous studies as well. Currently, no AFT exists to replace diesel trucks with 500 horse power [6,31,36]. Technology improvement and setting new standards for hydrogen and biogas trucks, therefore, are a necessity [14].

Dissimilar to *alternative fuels pricing policy* and *service quality of the manufacturers*, *maintenance costs* positively affect the choice probability of hydrogen and biogas trucks. If all ITCs agree *maintenance costs* are completely important, the choice probability of the alternative increases by 21% (Figure 3). Based on previous studies, BETs are found to have high *maintenance costs* after four years of driving [23,31]. In addition, BETs and CNG trucks' system inefficiency are among the problems [6,34]. Thus, high *maintenance costs* are deterrent for ITCs to choose BET, CNG, and LNG trucks in previous studies as well.

Refueling time has a positive influence on the third alternative in this study as well. Compared to BET, biogas trucks have much lower *refueling time*. It makes biogas trucks much more preferable [52]. To check the marginal effect of this variable, a scenario was conducted. In this scenario, it was assumed all ITCs chose *refueling time* as the main

advantage of hydrogen and biogas trucks compared to the other mentioned characteristics (including maximum driving range, tank capacity, and fuel price). The results demonstrated a 6% increase in the choice probability of hydrogen and biogas trucks.

Finally, the carried cargo type affects AFT choice. *Dangerous cargo* has a deterrent effect on CNG and LNG truck preferences. *Bulk cargo, liquefied bulk cargo, and containerized cargo* help induce CNG and LNG truck preferences. Lastly, the model shows that ITCs prefer hydrogen and biogas trucks to carry *roll-on/roll-off cargo*. The effect of cargo type, weight, and volume on the truck choice has also been discussed in previous studies [39,55].

5.2. MNL Model with the PCs

This section covers the model results generated with PCs and their elasticity (Figures 4, 5 and A1). Five PCs in the second model help explain ITCs' AFT choice behavior.

Figure 4. Elasticity of C2 (BET) with respect to changes in PCs.

Figure 5. Elasticity of C3 (hydrogen and biogas trucks) with respect to changes in PCs.

PC1 (AFT Practicability) and *PC2 (Policy Functionality)* are positively associated with the choice of CNG and LNG trucks. Probably, ITCs believe CNG and LNG trucks are more functional than other trucks. In the questionnaire, 16% of ITCs chose these trucks as their preferred AFT too. In addition, the model results showed that the current policies much more positively affect the market shares of the CNG and LNG trucks. In addition, like the previous model, ITCs prefer to carry *bulk cargo* and *containerized cargo* with these trucks. Figure 6 represents the results of the direct and cross elasticity. A 1% increase in *PC1* (meaningful in the first alternative) corresponds to 1.39% increase in the choice probability of CNG and LNG trucks. In addition, the direct elasticity of *PC2* and cross elasticity of other PCs scarcely affect the choice probability of the alternatives.

PC1 (AFT Practicability) has a positive coefficient in the second alternative as well. A BET is the second chosen AFT in the questionnaire as well, yet ITCs care less for environmental issues. *PC3 (Environmental Concerns)* has a negative association with this alternative. In addition, ITCs prefer BETs to carry *dangerous cargo*. Nevertheless, they do not find it suitable for *liquefied bulk cargo*. Figure 4 shows the direct and cross elasticity result. *PC1* (meaningful in the first alternative) with a 1% increase decreases the choice probability of BETs by 1.73%, whereas the direct elasticity of *PC1* (in BET choice) ultimately increases the choice probability by 0.14%. Furthermore, other PCs' elasticity barely changes the choice probability of the alternatives.
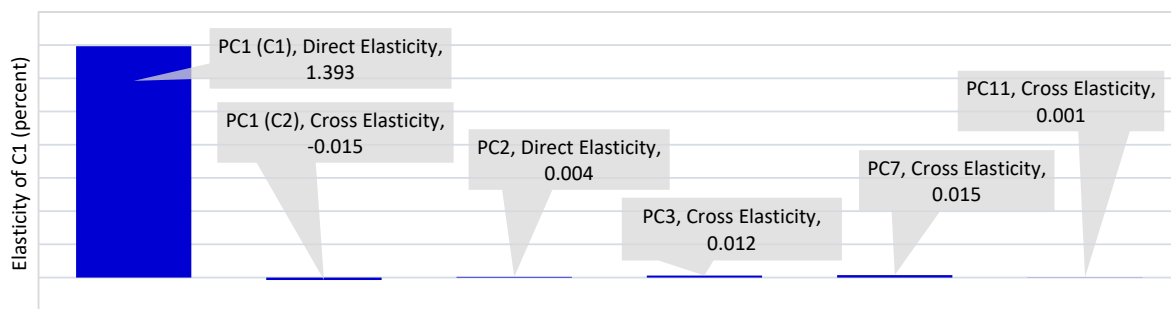
Figure 6. Elasticity of C1 (CNG and LNG trucks) with respect to changes in PCs.

PC7 and *PC11* have negative coefficients in the third alternative. AFT characteristics and environmental issues are drawbacks of the hydrogen and biogas trucks. Calculations show high GHG emissions in the supply chain of these fuels [53]. Probably, ITCs also worry about GHG emissions of the recycling procedure of these trucks (with reference to Table 2, which demonstrates the linear combination of PCs). Nevertheless, like the previous model, the shorter *refueling time* of biogas trucks helps elevate their market share. Figure 5 illustrates direct and cross elasticity results. Compared to other PCs, a 1% increase in *PC1* has a greater impact on choice probability.

6. Conclusions

Several methods have been employed to analyze AFT choice behavior in domestic land transit in previous studies. Analyzing this issue in international land transit is necessary; by passing through various countries, the AFT market share faces other barriers [14,15,43]. Thus, cognitive, environmental, policy, practical, and economic issues affecting ITCs' AFT preferences within the Europe–Iran international trade route were evaluated in this study. The online questionnaire was answered by 684 company managers across 20 countries in Europe and Iran.

The extracted eleven PCs revealed the original variables contributing to the AFT choice behavior. Considering the loadings above 0.2, the first PC (practical variables), the second PC (policy variables), the third PC (environmental variables), the fourth PC (cognitive variables), and the fifth PC (economic variables) feature the importance order of the variables for the ITCs. In addition, the generated two MNL models uncovered the variables influencing AFT choices in international land transit. The results of the MNL Models are summarized in Figure 7.

The model with Likert scale variables illustrates that tank-to-wheel GHG emissions, low noise pollution, unsuccessful short-term alternative fuel pricing policies, and social responsibility do not elevate AFT market shares. Besides the battery capacity of BETs, the top speed of BETs and the short refueling time of biogas trucks are important for ITCs in this study. Moreover, each additionally owned CNG truck, the service quality of the manufacturer, and high maintenance costs deter ITCs from choosing AFT. From the mentioned variables, AFT top speed, social responsibility, and alternative fuel pricing policy have the highest marginal effect.

The effectiveness of mentioned variables has also been argued in previous studies. Tank-to-wheel GHG emissions and social responsibility are not an important priority for ITCs [30,36,49]. As an advantage of BETs, low noise pollution does overcome its problems. Low driving range [54] and not addressing economic and political issues in the currently implemented regulations [55] are among the problems. It is believed that logistics planning has been connected to AFT top speed [17]. Furthermore, each additionally owned CNG truck has a detrimental effect on BET market shares [8]. Battery capacity and service quality of the manufacturers need improvement [14,31,36,50,56]. Maintenance costs and refueling time negatively affect the choice of BET, CNG, and LNG trucks [23,56]. Short-term pricing policies also decrease the market shares of hydrogen and biogas trucks [31,39,51].
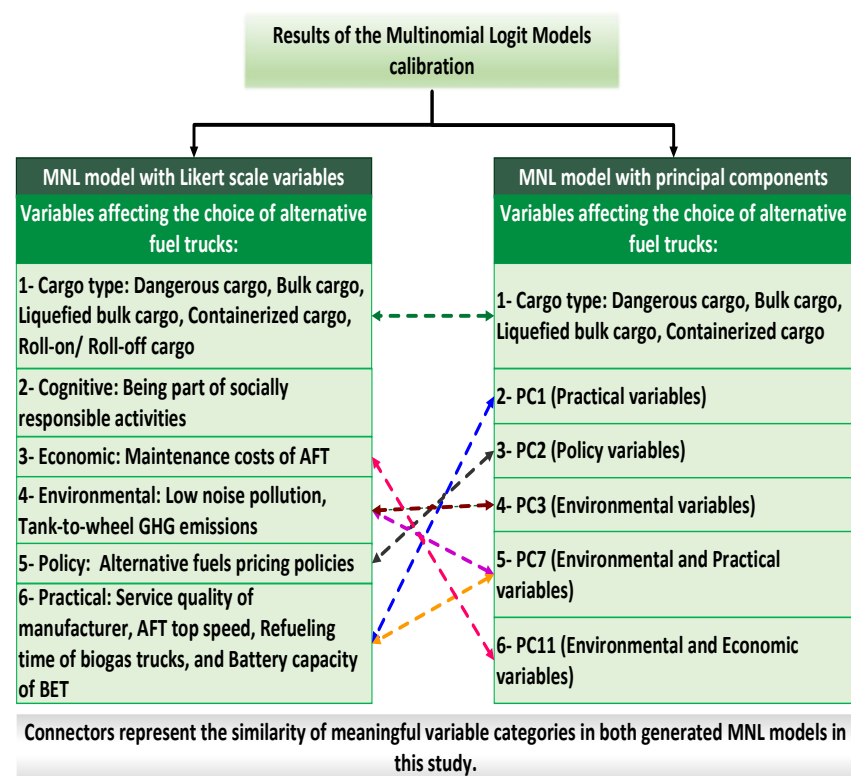
Figure 7. Illustration of the meaningful variables in the generated multinomial logit models.

In the second model, five PCs help explain the AFT choice behavior of the ITCs. PC1 (AFT practicability) positively affects BETs, CNG trucks, and LNG trucks' choice probability. It accords with the result of the first model illustrating the negative influence of practical issues on the choice probability of hydrogen and biogas trucks. In addition, compared to other PCs, a 1% increase in PC1 has a more considerable influence on the choice probability. The positive coefficient of PC2 (Policy functionality) in the alternative of CNG and LNG trucks indicates the current policies have been much more practical for CNG and LNG trucks only. It is also a reflection of the results of the first model. Alternative fuel pricing policies negatively affect the choice probability of BETs in the first model. In line with the first model, ITCs care less for environmental issues, and PC3 (Environmental concerns) has a negative association with BETs. In addition, the negative coefficient of PC7 shows ITCs have a negative opinion of the characteristics of hydrogen and biogas trucks. It can be related to the fact that GHG emissions in the supply chain of these fuels are considerable [3]. Finally, like the model with Likert scale variables, refueling time positively affects the choice probability of biogas and hydrogen trucks.

The current study found a meaningful relationship between cargo type and AFT choice. The generated models show ITCs do not find CNG and LNG trucks safe for carrying dangerous cargo. ITCs prefer BETs for this purpose. Yet to carry bulk and liquefied bulk cargo, containerized cargo, and roll-on/roll-off cargo, they prefer CNG and LNG trucks. The effect of cargo type has also been discussed in previous studies [39].

This study urges policy makers and AFT manufacturers to implement cognitive, environmental, policy, practical, and economic factors to help ITCs adopt alternative fuel trucks (AFTs) for international land transit. Challenging prevailing beliefs, the study highlights the significance of practical aspects, such as battery capacity, top speed, and refueling time, while questioning the impact of factors, such as greenhouse gas emissions and short-term pricing policies. It also emphasizes the need for improvements in battery capacity and manufacturer service quality to promote greater AFT adoption. Additionally, the study emphasizes the importance of tailoring AFT solutions to different cargo types. Overall, it advocates for an approach to meet the expectations of ITCs and encourage

the use of alternative fuels. This fact helps us to prioritize sustainability and reduce the environmental impact of the transport sector.

Limitation and Future Work

The importance of cargo type, cognitive, environmental, practical, and policy issues is revealed by the generated models. This study is limited to alternative fuel choice analysis. Future study suggestion is a secondary powertrain choice analysis for hybrid trucks. ITCs who chose none of the AFTs are not included in the MNL models in this study. Therefore, for future studies model calibration on these companies and revealing possible discouraging factors affecting their choice is suggested. Finally, in this study, ITCs' AFT choice analysis is based on current AFT characteristics. Future technology development may change views of ITCs and their AFT choice. Further analysis on this issue is also advised.

Appendix A

Table A1. Details of the references of the questionnaire.

Reference	Method	Country/Brand	Type of Vehicle	Analyzed Subject or Fuel
[14]	Conjoint choice-based analysis	Germany	Truck	Battery electric, CNG, Hydrogen, LNG
[17]	Cost estimation model	USA	Truck	Fuel-cell electric truck, Battery electric, Diesel, Hydrogen
[19]	Logistic regression	Spain	Car	Battery electric
[24]	Life cycle assessment model	USA	Vehicle	Hybrid vehicle, Battery electric vehicle
[26]	Factor analysis	Slovenia	Car	Alternative fuel (not specified)
[28]	Total cost of ownership (TCO) model	Sweden	Vehicle	Battery electric
[29]	Macro-level analysis of GHG emission of electric vehicles	United Arab Emirates	Vehicle	Battery electric
[36]	Mixed logit and multinomial logit models	USA, California	Vehicle	Battery electric, CNG, Methanol
[38]	Principal component analysis and factor analysis	Britain	Hybrid car	Emerging new technologies with alternative fuel
[39]	Cost minimization model	Navistar E-Star, Smith Newton, Isuzu N-Series	Truck	Diesel, Battery electric
[43]	Pearson's linear correlation test	Europe	Truck	Battery electric
[49]	Multiple linear regression analysis	Australia, Canada, Europe, USA	Vehicle	Battery electric
[50]	GHG emission analysis of bio-methane gasses	Europe	Heavy-duty vehicle's engines	Bio-methane
[53]	Multinomial logit model	Sweden	Car	Battery electric, Biogas, Diesel, Ethanol, Gasoil
[54]	Delphi method	Germany	Truck	Battery electric, CNG, Hydrogen, LNG
[55]	Multi-criteria analysis of policy measures to support battery electric freight vehicles	Germany	Truck	Battery electric
[56]	Principal component analysis and multinomial logit model	China, Indonesia, Japan, Philippine, Thailand, Vietnam	Car	Choice of public transport instead of private cars

Appendix B

Table A2. References of the questionnaire.

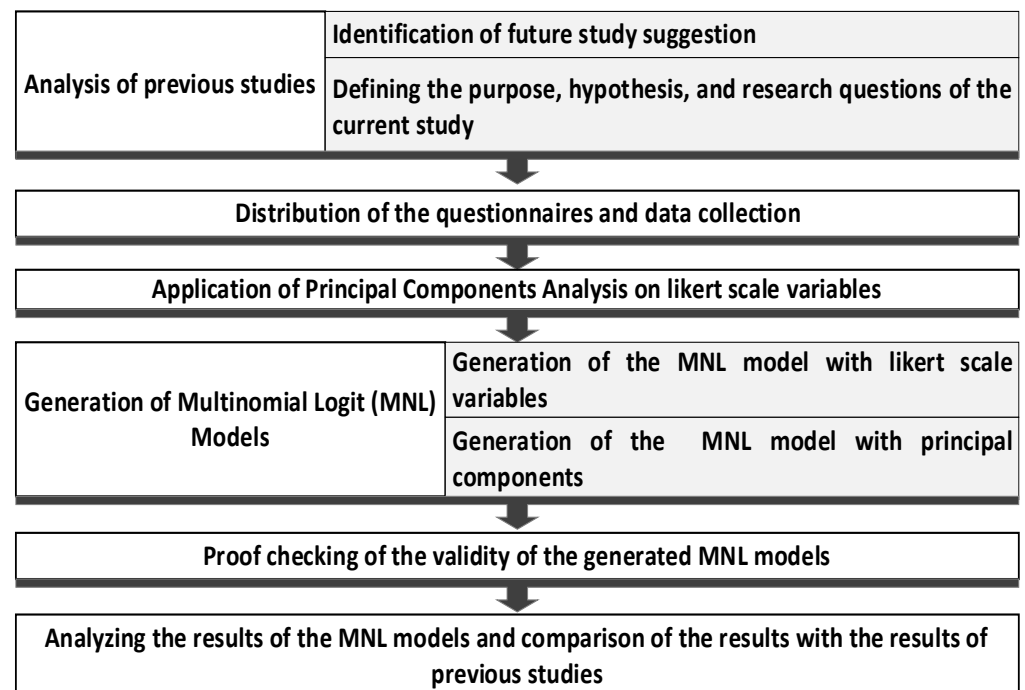| Variable Category	NO	Item	Reference
Cognitive	1	AFT has the required performance.	[13]
	2	AFT top speed is important for me.	[28]
	3	By using AFT and new technology, I will be proud.	[13]
	4	By using AFT, I will feel superior.	[13]
	5	I would like to be a leader in environmental-friendly technologies.	[3,53]
	6	I cannot rely on AFT and new technology.	[3,53]
	7	I would like to be part of socially responsible activities.	[3,53]
	8	I am excited about new technologies and innovations.	[3,53]
	9	The brand and model of the truck is important for me.	[20,33]
Environmental	10	The low GHG emission of trucks is important for me.	[3,33]
	11	The low noise pollution of trucks is important for me.	[3,33]
	12	The environmental effects of AFT manufacturing will affect my decision.	[3,50]
	13	The environmental effects of recycling AFT parts will affect my decision.	[3,50]
	14	The well-to-tank GHG emission will affect my decision.	[1,3]
	15	The tank-to-wheel GHG emission will affect my decision.	[1,3,4]
Practical	16	Refueling time	[4,11,30]
	17	The maximum driving range	[4,17]
	18	The refueling safety	[3,33]
	19	Truck weight	[53]
	20	Maximum payload capacity of AFT	[3,17]
	21	Vehicle size and loading space dimensions	[28]
	22	The service quality of manufacturer	[3,32]
	23	Availability of alternative fuel station	[3,40]
	24	Manufacturer's guaranty and warranty	[3,33]
	25	Cabin design (ease of accessibility)	[3,53]
	26	Availability of alternative fuels in petrol station	[28]
	27	Driver comfortability	[54]
	28	AFT acceleration time	[28]
Economic	29	Alternative fuel cost	[3,11,17]
	30	Maintenance costs of AFT (tax, duty, and insurance)	[3,4,17]
	31	Service costs of AFT	[3,28]
	32	AFT purchase cost	[3,11,17]
	33	Second-hand AFT sale value	[3,11,17]
Policy	34	Companies tax exemption in case of using AFT	[53]
	35	Discount in custom tax and duty charges in case of using AFT will affect my decision.	[3,53]
	36	Effect of entering low-emission zones on AFT purchase	[3,24]
	37	Effect of entering low-noise zones on AFT purchase	[3,24]
	38	Financial incentives when purchasing/operating an AFT	[3,24]
	39	Effect of government loans with no or low interest rate to help to buy AFT	[3,24]

Appendix C

| Analysis of previous studies | Identification of future study suggestion |
| | Defining the purpose, hypothesis, and research questions of the current study |

Distribution of the questionnaires and data collection

Application of Principal Components Analysis on likert scale variables

| Generation of Multinomial Logit (MNL) Models | Generation of the MNL model with likert scale variables |
| | Generation of the MNL model with principal components |

Proof checking of the validity of the generated MNL models

Analyzing the results of the MNL models and comparison of the results with the results of previous studies

Figure A1. Details of methodology.

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