Research Article

Alternative Ways of LNG Transportation Selection and Risk Management in Perspective of Bangladesh: A Case Study

Ashraf Mahmud Rayed*[1], Swadhin Ghosh[2], Iffath Haque Nissan[2], Sheikh Ittehad Uddin[1], Farhan Tazwar Islam Tonmoy[1]

Abstract

One of the nations with the densest populations is Bangladesh. The nation's energy use is increasing progressively. One of the greenest forms of energy is LNG. Natural gas, a liquefied gas, uses ultra-low temperatures and purification. In this study, the assessment of LNG carrier vehicles was evaluated from the perspective of Bangladesh. A cryogenic liquid tanker truck, called an LNG carrier vehicle, was found in the survey to carry liquefied natural gas in an environment with extremely low temperatures. Even though LNG is flammable, explosive, cryogenic, and has other characteristics, the safety design of an LNG carrier vehicle is crucial for the security of road transportation. Time consumption analysis and economic section analysis were conducted, and the truck was found to be the ultimate solution. LNG cryogenic liquid storage tanks, trailer running gear, piping systems, a control box, and other parts are often found in LNG carrier vehicles. Utilizing statistical tools, the validity of the survey and its findings will be evaluated by the Statistical Package for the Social Sciences (SPSS). The safety design study for these two systems was the topic of this work. A report on the compatibility of the best method for transporting LNG within all feasible safety conditions will be made possible by the research.

Keywords: LNG; Transportation; Sustainability; Risk management; Energy.

Introduction

Liquefied natural gas (LNG) is used as a fuel for long-distance, over-the-road trucking. The main component of LNG, methane, is a potent greenhouse gas. Gasoline, diesel, and coal produce more CO2 per unit of energy, whereas methane produces less CO2. As a result, industrial infrastructure methane emission rates have been underestimated [1]. Current and future infrastructure emissions must be low enough to offset methane's global warming potential (GWP) to benefit from methane [1], [2]. Bangladesh's energy landscape has historically been dominated by natural gas. At the beginning of the past decade, Bangladesh realized that its natural gas supplies would not last long, and by the end of the decade, the country's domestic gas output had begun to decline. Because the infrastructure is mostly reliant on gas, Bangladesh has no choice but to shift to Liquefied Natural Gas (LNG) to satisfy the present demand [3]. Gas was the dominant energy supply source in Bangladesh in FY2020-21 (MoPEMR, 2021). In the power industry, the situation is considerably worse. In the same fiscal year, the percentage of gas-based power plants (installed capacity) was 52% (BPDB, 2021). Local gas output in the nation was 892 billion cubic feet (Bcf) in fiscal year 2020–21, an 8% decline from fiscal year

Affiliation:

[1]Department of Mechanical Engineering, Chittagong University of Engineering and Technology, Raozan-4349, Chattogram, Bangladesh.

[2]Department of Petroleum and Mining Engineering, Chittagong University of Engineering and Technology, Raozan-4349, Chattogram, Bangladesh.

Corresponding author:

Ashraf Mahmud Rayed. Department of Mechanical Engineering, Chittagong University of Engineering and Technology, Raozan-4349, Chattogram, Bangladesh.

2016–17, according to the Ministry of Power, Energy, and Mineral Resources (MoPEMR, 2021) [4]. In its Gas Sector Master Plan 2017 (GSMP 2017), the country opted to go with LNG. Bangladesh began importing LNG in 2018 due to rising gas consumption and declining domestic output, and demand is likely to rise further. According to the GSMP, daily gas consumption will exceed 500 million standard cubic feet (MMscf) in 2030 [5]. Methane makes up the majority of liquefied natural gas, which is a colorless, odorless, and non-toxic liquid. In order to assure safety, carrier trucks transporting LNG must first pass a certain design test. It is an additional natural gas energy source created by gas pressure below -162 °C. Liquefied natural gas is ideal for storage and transportation because it has a volume that is around 1/600 that of gaseous natural gas and a lighter mass that is only about 1/45 that of water[6]. LNG may be employed in a variety of industrial settings throughout the globe and is essential for advancing the transformation of the energy consumption structure in all energy superpowers. The density of liquefied natural gas ranges between 0.420 and 0.46 t/m3, its ignition point is 650 °C, and its boiling point is 161.25 °C. The percentage of its explosion ranges from 5 to 15% [7].

Since methane makes up the majority of natural gas, its characteristics are comparable to those of pure methane. Methane, or natural gas, can cause headaches, dizziness, anemia, forgetfulness, difficulty breathing, and tachycardia in humans. It might be challenging to locate the leak when a leaking accident happens since natural gas has no color and no odor. LNG is one type of natural gas that is converted into a liquid using cryogenic technology because it exists naturally at low temperatures [2].

The LNG supply chain in Bangladesh may be divided into four separate stages, beginning with import and ending with end users such as power plants [4].

Bangladesh imports LNG via long-term contracts as well as on the spot market. The Gas Transmission Firm Limited (GTCL) is the single company responsible for gas transmission in Bangladesh. It is a subsidiary of the Bangladesh Oil, Gas, and Mineral Corporation, popularly known as Petrobangla, which is controlled by the Government of Bangladesh (GoB). Power plants are the primary customers of these gas distribution firms. Rupantarita Prakritik Gas Company Limited (RPGCL), another Petrobangla subsidiary, has been tasked with carrying out LNG-related operations in the nation [5]. There are three primary models for transporting LNG: naval transport, pipeline transfer, and tanker transport. Among them, natural gas pipeline transportation and sea transportation have given a large number of natural gas transportation projects an efficient and dependable approach. Because LNG is liquid and has low temperature characteristics, LNG carrier vehicles must adapt to the polyhedral broader market while also ensuring transportation safety under more difficult road conditions [8]. The research paper is organized to investigate the best LNG transport along with LNG risk management while maintaining the highest level of safety. It is possible to assess the probabilities of moving LNG through alternative routes in Bangladesh.

Literature Review

Several academics have addressed the problem of risk assessment in risky commodity transit during the last two decades [9][4]. This research concentrated on pipeline transportation [10], railway transportation [11], [12], and road transportation [13], [14]. Three issues are covered in HazMat (Hazardous Materials) road transport research. The first is concerned with techniques for enhancing emergency response based on route characteristics, weather conditions, and traffic variables. The second approach is based on surveying and accident risk analysis techniques based on historical data to reveal accident features such as the number of occurrences, accident effects, and determination of cause variables [15]. The final topic focuses on strategic planning to enhance truck ability and route.

The Environmental Defense Fund (EDF) and West Virginia University's Center for Alternative Fuels, Engines, and Emissions (CAFEE) studied pump-to-wheel natural gas emissions in heavy-duty transportation. They included Compressed Natural Gas (CNG) cars and stations and LNG vehicles and stations. Emission projections were also based on research-related technological and practice changes
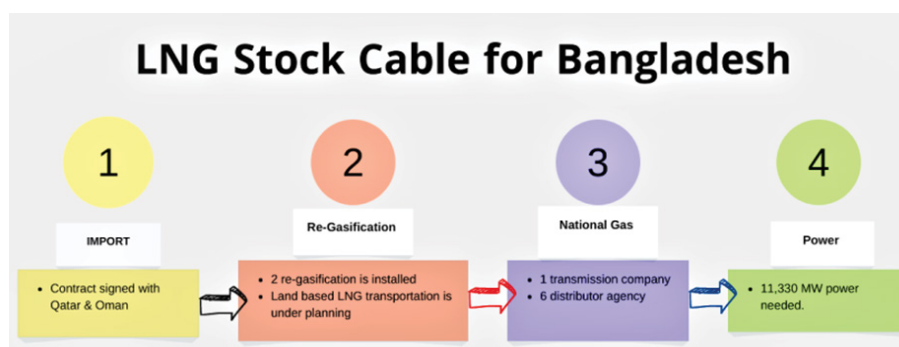

Figure 1: LNG Supply Chain for Bangladesh

[13]. Accidents involving dangerous products can have disastrous effects on individuals, the environment and the economy. Transporting risky products safety is now a hot subject in transportation planning. Regulations governing the international transportation of dangerous goods by rail, road, or inland waterway Automatic Dialogue Replacement (ADR), Application Delivery Network (AND), and Receiving Inspection Detail Instruction (RID) [3].

Regarding human risks, vehicle transportation of dangerous products puts individuals on the road (users) and those along the roads at risk. The severity and length of an impact can be affected by a number of factors, including the nature and danger of the items being transported and the type of collision. Road components such as straight, curving, tunnel, bridge, and so on. Enclosed region crossing; pavement structure; speed [16].

The relationship between traffic congestion and the frequency and seriousness of traffic accidents is extremely concerning. Traffic congestion and road accidents are two significant external costs of transportation created by road users [17], with significant consequences for road users and the community. One of the significant goals of transportation policymakers is to reduce their impacts. Traffic congestion is common, especially during rush hour in heavily populated regions [18].

Shefer and Rietveld conducted additional research on the relationship between roadway congestion and safety. Using the previously utilized theory, they examined fatality rates throughout the day. Shefer hypothesized an inverse link between traffic congestion and road deaths, with the volume over capacity ratio used to assess the amount of congestion. They discovered that the fatality rate is lower at peak hours than during other times of the day. Due to a lack of data, they tested a suggested model with a simulated dataset rather than real-world data [19]. Traffic congestion had no effect on the frequency of accidents, a study has shown. Quddus studied vehicle incidents involving personal injuries on the M25 highway in London, United Kingdom (UK) and found no significant difference between traffic congestion and accident frequency. Despite this finding, the authors emphasized that further research is required to comprehend traffic congestion's impact on accidents completely. Using observed traffic flow patterns on England's motorways from 2007 to 2013, the author used new data sources and contemporary identification techniques to assess the influence of an accident's incidence on observed average speeds. The data has never been utilized in an academic publication before, so the outcome of his research will undoubtedly be intriguing [10]. In connection with the primary topic of this work, Fabiano studied all forms of traffic accidents, including PDO-ss (Accidents with property damage only). The authors, authors determine the frequency

by geometric variables, slopes, the number and width of lanes, the kind of road segment, and traffic flow [1], [3].

Research Methodology

Bangladesh's stance on risk management and alternate LNG shipping methods was not documented until this study.

Data collection was completed using a questionnaire. Categorization, investigation and sample characterization was included in the analysis of the survey. The questionnaire assessment was divided into two sections:

1. Graphical visualization of participants and

2. Participants future dynamic routing assessment.

Analytical, sociological, and economic factors were incorporated in Part 1 of the questionnaire. The last part contains around thirteen questions, which were vital for the analysis. The most concerning issues were infringements and errors. Before presenting the question to the audience, we made important revisions since we were quite worried about its efficiency. The survey was then shared on different platforms and was completed physically while visiting some plants where LNG is directly used. This enabled an in-depth study based on alternate LNG shipping routes from Bangladesh's perspective.

Survey

In 2021–2022, Google Forms was used to complete the "An Online Case Study on LNG Transportation and Risk Management Properties of Bangladesh" questionnaire. The drivers of public transit in Bangladesh, however, do not properly utilize the internet. As a result, fewer people than anticipated responded to the poll online. The questionnaire was disseminated on social media channels, including Facebook and Instagram. As a result, the trial size for the targeted refined and cyberspace-using drivers is small.

Using Statistical Package for the Social Sciences Statistics (SPSS) for Windows, version 27.0, the questionnaire data's validity and reliability were assessed (SPSS Inc., Chicago, Information Logical (IL), USA). The questionnaire used to gather the data and the conclusions reached are reliable and valid. There was use of the Cronbach's alpha test, which is regarded as realizable and valid by experts. The alpha score for a person is 0.623 (Tables 1 and 2). Cronbach's alpha is the identifier of inner connections and the consistency of the set of questions. Throughout the world's research, the test using the software's result is taken as the most consistent and scale-reliable. It can be written as a formula for Cronbach's alpha:

$$\alpha = \frac{N\,\bar{c}}{\bar{v} + (N-1)\bar{c}}$$

Here

Table1: Case processing summary.

		N	%
Cases	Valid	50	81
	Excluded ᵃ	12	19
	Total	62	100

ᵃList wise deletion based on all variables in the procedure.

Table 2: Reliability test result.

Reliability Statistics	
Cronbach's Alpha	N of Items
0.623	15

N = Number of items,

$\bar{c}$ = Average inter-item covariance among the items and

$\bar{v}$ = Average variance.

According to the formula, (Cronbach's alpha) is directly proportional to N (number of items) and proportional to the average inter-item covariance among the items (while keeping the number of items constant).

Data Sorting & Fitting

Sixty-two participants, whose representation of the driving community in Bangladesh was confirmed prior to screening, finished it. The data has been validated and examined to ensure that it is real and legitimate. Out of 62 instances, 12 have been deleted for the reasons listed below:

1. Missing values in lines were eliminated if there were more than 20% of blank items.

2. Uninterested respondents who chose the same pertinent replies were deemed to have given biased answers, and their responses were removed from the database.

The data were sorted and a final selection of 50 entries was made. For the correspondent, it appears that all of the participants are male. Three sectional data was analyzed for the study.

1. Best transit selection

2. Vehicle design optimization

Best land way carrier selection

Mainly, LNG is carried out using large pipes and ships. Pipes are required to transport LNG safely from storage to a vehicle. Three different types of LNG carriers (railways, trucks, and small ships) are under consideration for the research. The survey's findings will show us the proper path for transporting LNG. The vehicle that will be used for land-based purposes will be chosen based on a few pre-conditions and pre-analysis. In the economic analysis, consider reducing LNG loss for carrying, construction, and maintenance costs.

The vehicles must have their protection tested in order to select the best land carrier. At the destination, the carrier will use the pipe to transfer the LNG to bulk storage there.

Data Analysis

Descriptive analytics, economical position analysis, less time-consuming path selection, and safety measurement are, according to the general public and the authority, the analyzing portions of the collected data. Those aspects are detailed below.

Descriptive Analysis

Descriptive data is mostly about how current and past data on the distribution of observations in variables relate to each other. This research details the optimal transit option and its safety objective, according to the transport agency. LNG is one of the costliest gases imported from abroad. According to the survey's (Figure 3) findings, trucks are currently the best option for transferring gas because it takes less time than using other LNG transit, whereas LNG carriers the truck, the ship, and the train have 52%, 22%, and 26% of the votes, respectively train have 52%, 22%, and 26% of the votes, respectively. The mean value of the specific data is 1.70, while the standard deviation is 0.814.

LNG trucks are the most convenient form of transit. Survey data (figure 4) shows that the rate of risky life if the transit causes any accidents is the main reason for the safety of the transit, and it gets about 66% of the people's vote.

Economic Analysis

A fundamental component of economic analysis is the weighing of potential costs against possible benefits. Its purpose is to do research about the influence a project will have on people's welfare. Figure 5 depicts that trucks, ships, and trains have a percentage of 10%, 66%, and 24%, respectively, for maintenance cost, which clearly shows the real picture from the perspective of Bangladesh, where trucks are the most convenient solution to transfer LNG inside the country. Meanwhile, Figure 6 shows that about 42% of respondents chose both the truck and the ship as LNG carriers, while only 16% chose the train. The specific data have a mean value of 2.00, and the standard deviation is 0.926.

Time Consuming Analysis

The main pillars of the transit selection will be dependent upon the economic perspective, safety issues, and time-consuming purpose. According to the feedback (figure 7), participants are thinking that economic purpose should be the foremost criteria for selecting transit. The safety issues will be directly connected to selecting the route mainly. Figure 8 shows that trucks are now the most effective method for moving gas in a timely manner since they are more cost-effective than other LNG transit options.
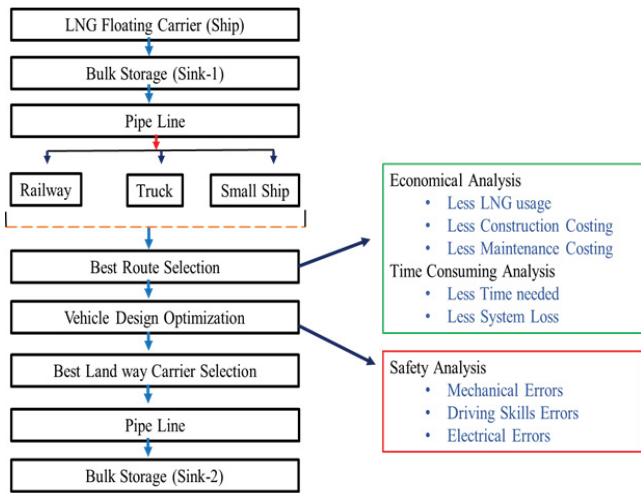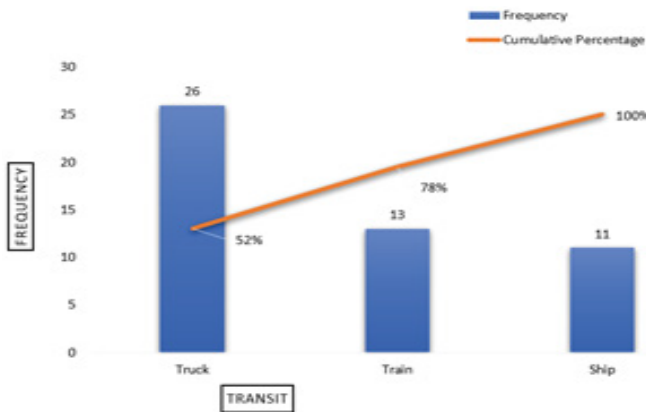
Figure 2: Flow Chart of plan to transfer LNG

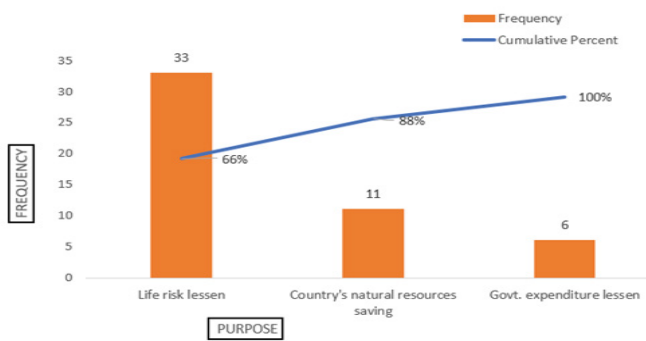**Figure 3:** Details data of respondents for transferring gas.

Figure 4: Details data of respondents for transferring gas using safety purpose transit.

Safety analysis

The SPSS program's findings indicate that trucks are currently the best option for transporting gas since, in comparison to other LNG transit choices, they will be least impacted in the event of a natural disaster in Bangladesh. From figure 9, the truck, ship, and train received 54%, 26%, and 20% of the ballot, respectively. The LNG carrier will be heavily reliant on the route chosen for truck transit. According to survey respondents (from Figure 10), transporting LNG via rail is the best alternative for exploration or fire escape. The truck and ship have the highest value of the occurring exploration percentage, with values of 76% and 18%, respectively.

For vehicle design optimization and safety issues, three different types of major errors are taken into account for proper design conditions. Mechanical, electrical, and driving skill errors are preferred errors for design.

Transporting LNG via any transit system while maintaining safety issues is the final criteria. However, from the figure, it is clear that mechanical errors, electrical errors, and driving skill errors will be a vital part of vehicle design. The pre-conditions and the design constraints need to be pre calculated. Therefore, it is obvious that the LNG carrier will depend much on the route choice for truck transit.

Results & Discussion

The study's ultimate solution is discovered to be in the form of a survey. The targeted issues were the best transit pathway selection and proper safety. The truck service is the most effective route for LNG transit. A survey finds that most people favor using trucks for transportation over ships or trains. Manufacturing a truck is much more economical than manufacturing trains and ships. The survey also finds that constructing a truck is less expensive than building a ship
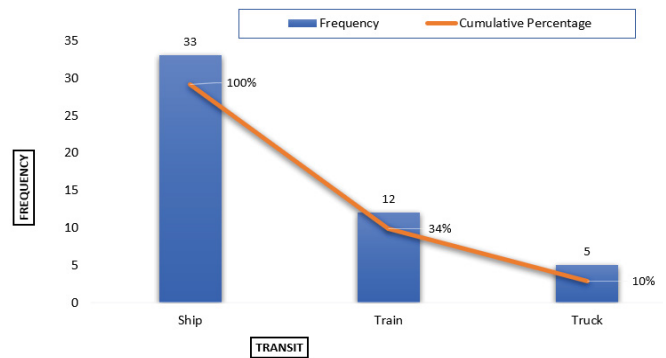

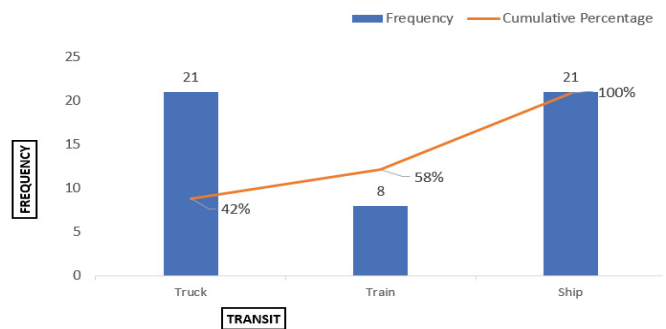**Figure 5:** Details data of respondents for transferring gas at higher maintenance costs.

Figure 6: Details data of respondents for economical LNG transport.
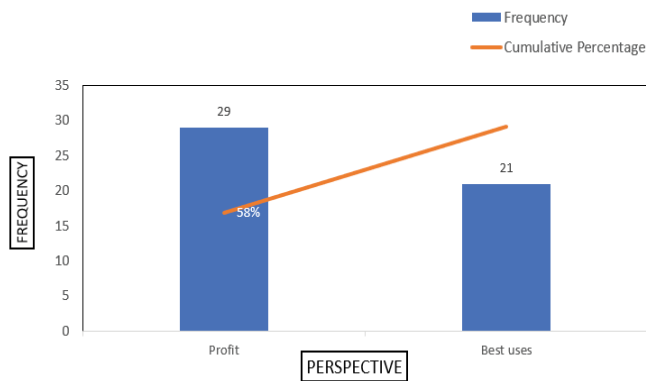
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Figure 7: Details data of respondents for choosing transit in different perspective.
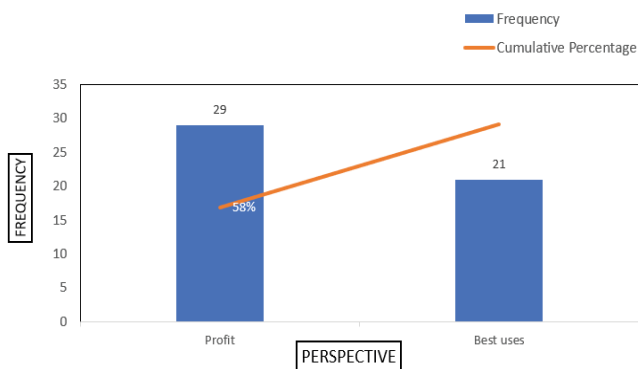

Figure 8: Respondent data for most effective method for moving gas in a timely manner.
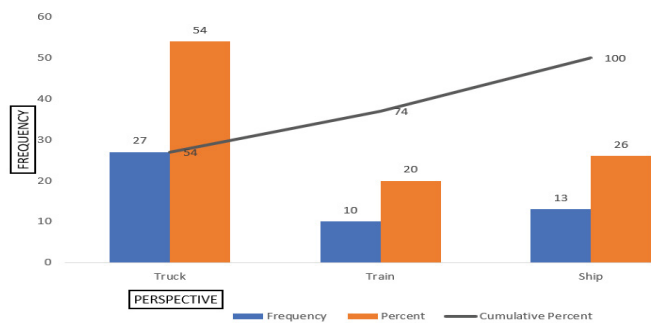

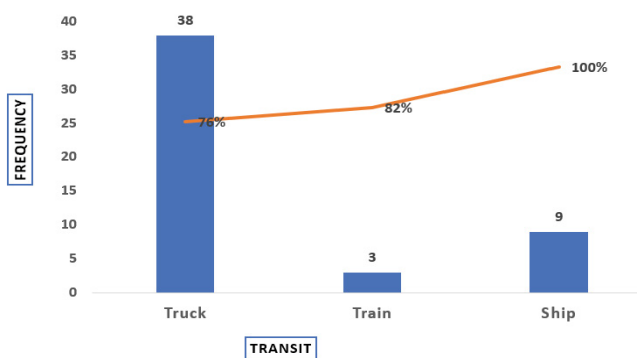**Figure 9:** Details data of respondents for carrying LNG at least affected in natural calamity.

Figure 10: Details data of respondents for transit that will be affected of explosion
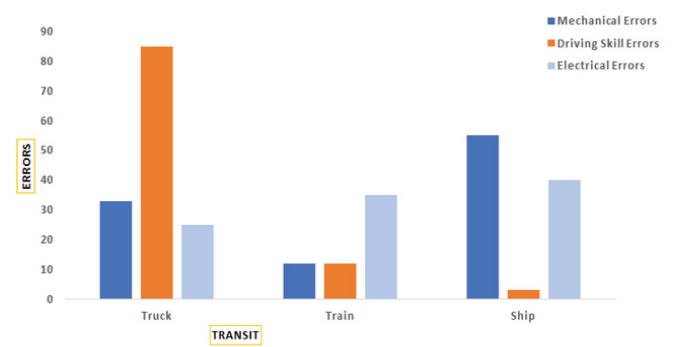

Figure 11: Details data of drivers for transit safety analysis.

or train, according to the authority. The maintenance charge and recurring check fees for trucks are less than for the train and ship.

After analyzing data for safety purposes, the results indicate that the railway will be less impacted by a fire exploration than the truck, which will result in a massive exploration. Any gas exploration will surely result in a significant number of fatalities as the truck moves between the cities. Error is the state or condition of being wrong in conduct or judgment. Errors made while driving are one of the notable issues in moving LNG from one location to another. For land transportation, mechanical faults can happen at any time, but they can be minimized by careful design. One of the most serious transportation faults is an electrical fault, which has a tenuous connection to driving abilities. If it happens while driving, it compromises safe driving.

Economic analysis results express that trucks are the best solution to carry LNG in Bangladesh. Construction and maintenance costs are much lower for trucks as a method of transfer. The travel time is comparably shorter than that of trains or ships. Because the ports are smaller, ships are not a better option to carry. The truck has the best option in every single segment. The system loss from losing LNG will be minimal for the truck. The errors can be reduced by designing a better structure for the vehicle for safety. It will be the best step to import some special advanced LNG carriers for some research work.

Conclusions

One of the crucial pieces of transportation equipment that transports liquefied natural gas (LNG) from producers to practical locations around the nation is an LNG carrier truck. The effects of an accident during shipping will be disastrous due to the LNG's cryogenic properties as well as the nature of flammables and explosives. The survey's findings demonstrate unequivocally that most individuals favor using trucks for transportation. From Bangladesh's perspective, the truck service is the most efficient method for LNG transit. In terms of cost and safety, building a truck will be less expensive than building a ship or railway. For land transportation, mechanical, electrical, and skill failures can happen at any moment. Finally, the risk state of safety was concluded.

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Although the safety performance of an LNG carrier vehicle has been improved now that it has been designed, there is still a possible safety concern. Regular maintenance and safety inspections are required.

References

1. RA Alvarez, SW Pacala, JJ Winebrake, et al. "Greater focus needed on methane leakage from natural gas infrastructure." Proc Natl Acad Sci U S A 109(17) (2012): 6435-6440.

2. S bin Amin and S Rahman. "LNG and LPG Market Development in Bangladesh." in Energy Resources in Bangladesh 10(2019): 67-71.

3. A Conca, C Ridella, and E Sapori. "A Risk Assessment for Road Transportation of Dangerous Goods: A Routing Solution." in Transportation Research Procedia 14(2016): 2890-2899.

4. M Abdullah, F Shah, Md AH 'Khondaker. "Economic and Environmental Cost Estimation of LNG Import: Revisiting the Existing Strategy of Imported LNG." 7(2022):1-20.

5. Annual Report. "Annual Report on Gas Production, Distribution and Consumption FY 2020-2021.Dhaka." 5(2021).

6. J Gao. "Safety design requirements of LNG carrier vehicle." Special vehicle press 10(2004).

7. F Alam, K Saleque, Q Alam, et al. "Indigenous and imported natural gas and the economic growth of Bangladesh: The challenges ahead." in Energy Procedia 160 (2019): 18-25.

8. MA Arefin, MN Nabi, MW Akram, et al. "A review on liquefied natural gas as fuels for dual fuel engines: Opportunities, challenges and responses." Energies 13(22) (2020): 1-19.

9. J Yang, F Li, J Zhou, et al. "A survey on hazardous materials accidents during road transport in China from 2000 to 2008." J Hazard Mater 184(1–3) (2010): 647-653.

10. X Liu, MR Saat, and CPL Barkan. "Integrated risk reduction framework to improve railway hazardous materials transportation safety." J Hazard Mater 260 (2013): 131-140.

11. B Fabiano, F Currò, E Palazzi, et al. "A framework for risk assessment and decision-making strategies in dangerous good transportation." in Journal of Hazardous Materials 93 (1) (2002): 1-15.

12. MR Saat, CJ Werth, D Schaeffer, et al. "Environmental risk analysis of hazardous material rail transportation." J Hazard Mater 264 (2014): 560-569.

13. B Fabiano, F Currò, AP Reverberi, et al. "Dangerous good transportation by road: From risk analysis to emergency planning." in Journal of Loss Prevention in the Process Industries 18(4–6) (2005): 403-413.

14. C Shew, A Pande, and C Nuworsoo. "Transferability and robustness of real-time freeway crash risk assessment." J Safety Res 46 (2013): 220-225.

15. X Guo and M Verma. "Choosing vehicle capacity to minimize risk for transporting flammable materials." J Loss Prev Process Ind 23(2) (2010): 220-225.

16. A Ambituuni, JM Amezaga, and D Werner. "Risk assessment of petroleum product transportation by road: A framework for regulatory improvement." Saf Sci 79 (2015): 324-335.

17. R Arnott and K Small. "The economics of traffic congestion." Am Sci 82(5) (1994): 446-455 .

18. D Shefer. "Congestion, air pollution, and road fatalities in urban areas." Accid Anal Prev 26(4) (1994): 501-9.

19. D Shefer and P Rietveld. "Congestion and safety on highways: Towards an analytical model." Urban Studies 34(4) (1997): 679-692.