Thesis Report

on

"Optimizing Road Transport Operations in Bangladesh's LPG Sector: Infrastructure, Safety, and Sustainability"

Submitted by:
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Program: MBA in Supply Chain Management
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Department of Business Administration
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Submitted to:
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Department of Business Administration
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Submitted for the partial fulfillment of the degree

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Sonargaon University (SU)
147/I, Green Road, Panthapath, Tejgaon, Dhaka

Date of Submission: January 03, 2026

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Letter of Transmittal

January 03, 2026

Mst. Marium Akter
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Subject: Submission of thesis report on **"Optimizing Road Transport Operations in Bangladesh's LPG Sector: Infrastructure, Safety, and Sustainability"**

Dear Madam,

With most respectfully to state that I am pleased to submit my thesis report titled **"Optimizing Road Transport Operations in Bangladesh's LPG Sector: Infrastructure, Safety, and Sustainability"**. This report is an essential part of my MBA degree requirements, and I had the privilege of completing my Thesis at renowned LPG operators' companies in Bangladesh. under your guidance. This report reflects the current delivery practices essential for organizations in our country. I have made an effort to include relevant details while keeping the report concise.

I kindly request your assessment of this report. Your feedback would be greatly appreciated. Thank you for your time and consideration.

Yours Sincerely,

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Declaration of Student

I am **Abdullah**, a student in the Master of Business Administration in Supply Chain Management program with ID: MSCM2401031019 at Sonargaon University. I want to sincerely state that the report titled **"Optimizing Road Transport Operations in Bangladesh's LPG Sector: Infrastructure, Safety, and Sustainability"** has been genuinely created by me. During the preparation of this report, I ensured full compliance with international copyright regulations. I also want to clarify that this report has not been submitted anywhere else for the purpose of obtaining a degree.

Yours Sincerely,

_____

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Letter of Authorization

I hereby confirm that the thesis report titled **"Optimizing Road Transport Operations in Bangladesh's LPG Sector: Infrastructure, Safety, and Sustainability"** is a genuine effort by Abdullah the research was conducted under my guidance. I also affirm that, to the best of my knowledge, the content presented in this report has not been included in any other project report or dissertation that led to the award of a degree to any candidate earlier, whether in the same context or a different one.

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Abstract

This thesis exposes how road transport operations for liquefied petroleum gas (LPG) in Bangladesh can be optimized across three interlinked dimensions: infrastructure, safety, and sustainability. Using a mixed-methods approach policy and industry document review, stakeholder interviews and a structured survey of drivers and depot managers the study identifies bottlenecks in road infrastructure and modal links, evaluates current safety practices and incident causes, and assesses opportunities to reduce emissions and improve fuel efficiency. Key findings show: inadequate dedicated LPG corridor design and depot access increases trip time and risk; safety gaps are driven by vehicle condition, driver training, and weak enforcement of standards; fuel inefficiency and empty-run ratios raise costs and emissions. The thesis proposes an integrated action framework, physical infrastructure upgrades, operational protocols and data-driven routing, a mandatory safety management system, capacity-building for drivers, and incentives for cleaner fleets to improve efficiency, reduce accidents, and advance sustainability while remaining feasible within Bangladesh's institutional and economic context.

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List of Acronyms

Acronyms	Abbreviation
BPC	Bangladesh Petroleum Corporation
BRTA	Bangladesh Road Transport Authority
CO_2	Carbon Dioxide
CTU	Cargo Transport Unit
GIS	Geographic Information System
IMDG	International Maritime Dangerous Goods
ITBs	Invitation to Bid
KPI	Key Performance Indicator
KPL	Kilometers Per Liter
LPG	Liquefied Petroleum Gas
M^3	Cubic Meter
MT	Metric Ton
NOx	Nitrogen Oxides
PO	Purchase Order
RFP	Request for Proposal
SOP	Standard Operating Procedure

Chapter: One
Introduction

1.1 Background of the study

LPG is a vital household and industrial fuel across Bangladesh. Road transport carries majority of cylindered LPG from import plant to distribution depots and retailers via bottling plant. The sector faces unique risks from hazardous cargo, infrastructure limitations (narrow urban links, congested highways), and environmental pressures. Optimizing road operations can lower logistics costs, reduce accidents and losses, and improve environmental outcomes.

1.2 Scope of the study

This study focuses on the movement of cylindered LPG across Bangladesh, specifically the road transport operations that connect import terminals and bottling plants to urban and rural depots. The scope is deliberately framed to capture the critical "middle mile" of LPG logistics—the stage where bulk shipments are broken down and distributed to depots before reaching end consumers.

The research does not extend to household or on-site handling of LPG cylinders at consumer premises, as those activities involve different risks and operational dynamics. Instead, the emphasis remains on the organized transport network that underpins the country's LPG supply chain.

By narrating the scope in this way, the study is able to:

- Examine how road infrastructure, depot access, and corridor constraints affect delivery times, safety risks, and costs.
- Assess the operational practices of transporters, including routing, vehicle utilization, and load consolidation.
- Identify systemic inefficiencies such as empty runs, fuel wastage, and scheduling delays.
- Explore opportunities for sustainability through better fleet management, and integration with alternative modes like waterways.

In short, the scope is designed to provide actionable insights into the segment of LPG logistics where optimization can deliver the greatest impact—improving efficiency, strengthening safety, and advancing environmental sustainability for Bangladesh's growing energy sector.

1.3 Objective of the study

Board Objective

Assess and propose optimized strategies for road transport operations in Bangladesh's LPG sector that improve operational efficiency, strengthen safety performance, and advance environmental sustainability.

Specific Objectives

- Map the current LPG road transport system including terminals, depot networks, typical routes, vehicle types and operational flows.
- Identify infrastructure bottlenecks (depot access, corridor constraints, bridge/clearance

limits) that increase trip time, safety risk and costs.

- Evaluate safety practices and causal factors of incidents across vehicles, drivers, depots and emergency response capabilities to quantify incident frequency and severity.
- Measure operational inefficiencies by estimating empty-run ratios, dwell times, route inefficiencies and fuel consumption per cylinder-km.
- Test and model operational interventions (route optimization, load consolidation, telematics, scheduling) to estimate potential gains in efficiency, safety and emissions.
- Develop a phased implementation roadmap and cost–benefit case with KPIs, pilot design and financing/incentive options to support scalable adoption by industry and regulators**.**

1.4 Research Methodology

This study uses a mixed-methods explanatory sequential design. It begins with questioner data collection and analysis to measure operational performance, safety outcomes, and emissions baselines, followed by qualitative & quantitative approach

Primary sources of data

- Surveys
- Experiments
- Personal Interviews

Secondary Sources of Data:

- Non-government documents
- Statistical data
- Research reports.
- Manuals,
- Journals,
- Official publications,
- Web sites,
- Relevant industry reports,

1.5 Significance of the study

This study provides actionable evidence for policymakers to update and strengthen regulations, vehicle standards, and routing permits for LPG road transport in Bangladesh, enabling targeted public investments that improve safety and traffic management without large-scale disruption.

By identifying practical operational measures—route optimization, load consolidation, telematics and depot quick-fixes—it offers transport operators concrete steps to reduce empty runs, shorten delivery times and cut operating costs, improving commercial viability while raising service reliability.

The economic analysis highlights cost savings from fewer accidents, lower fuel consumption and higher vehicle utilization, presenting a business case to attract financing, subsidies or incentives for fleet renewal and telematics adoption among small and medium operators.

Finally, the study builds institutional capacity by delivering reusable survey instruments, GIS templates and a pilot design that industry, regulators and researchers can apply for monitoring, scale-up and replication in other hazardous-cargo sectors and comparable emerging-market contexts.

1.6 Limitations of the Study

- Sample Size and Representation The study relied on a relatively small group of drivers, depot managers, and stakeholders. Although their perspectives are insightful, they may not fully represent the diversity of experiences across the entire LPG transport sector.

- Geographic Coverage Most of the data was collected from major hubs such as Dhaka and Chattogram. Remote and rural areas, where infrastructure and operational challenges can be very different, were not covered in depth.

- Self-Reported Data Surveys and interviews depended on participants' own accounts. While useful, self-reporting can sometimes introduce bias—drivers or managers may understate safety lapses or inefficiencies.

- Limited Telematics and GPS Data Only a small number of vehicles provided telematics information. This restricted the ability to model real time routing, fuel efficiency, and fleet performance across the sector.

- Time Constraints The research was conducted within a short timeframe. This prevented deeper longitudinal analysis or seasonal comparisons that could reveal variations in transport performance.

- Secondary Data Gaps Some regulatory documents and accident records were incomplete or outdated. As a result, certain assumptions had to be made in cost benefit modeling and risk analysis.

- Operational Confidentiality Several companies restricted access to detailed operational and financial data. This limited the depth of economic analysis and intervention modeling.

- Infrastructure Data Limitations Road condition assessments were partly based on stakeholder feedback rather than comprehensive engineering surveys, which may affect accuracy in identifying bottlenecks.

- Contextual Factors Political disruptions, fuel price volatility, and regulatory enforcement challenges were acknowledged but not fully modeled, even though they significantly influence transport operations.

- Technology Adoption Barriers Recommendations such as telematics and digital routing assume readiness for technology adoption. In reality, smaller operators may lack the financial or technical capacity to implement these solutions.

1.7 Structure of the thesis

This thesis is organized into eight chapters, each addressing a specific aspect of the research topic:

- **Chapter 1: Introduction**
  Provides the background, scope, objectives, methodology, significance, and limitations of the study.
- **Chapter 2: Literature Review**
  Reviews existing research and practices related to LPG transport, road freight operations, safety management, and sustainability, with a focus on the Bangladesh context.
- **Chapter 3: Conceptual Framework and Hypotheses**
  Presents the integrated framework linking infrastructure, operations, human factors, and regulatory environment to transport outcomes. It also outlines the hypotheses tested in the study.
- **Chapter 4: Research Methodology**
  Describes the mixed-methods approach used for data collection and analysis, including surveys, interviews, GIS mapping, and operational modeling.
- **Chapter 5: Data Analysis and Results**
  Analyzes the collected data to identify key inefficiencies, safety gaps, and environmental impacts in LPG road transport operations.
- **Chapter 6: Discussion**
  Interprets the findings, evaluates stakeholder perspectives, and discusses the implications for policy and industry.
- **Chapter 7: Conclusion and Recommendations**
  Summarizes the study's conclusions and proposes actionable recommendations across infrastructure, safety, operations, sustainability, and policy.
- **Chapter 8: Bibliography**
  Lists all references and sources consulted during the research.

Chapter: Two
Literature Review

2.1 LPG Transport Fundamentals

Liquefied Petroleum Gas (LPG) has become one of the most essential fuels for households and industries in Bangladesh. Because the country relies almost entirely on imports, the way LPG is transported from offshore terminals to end-users is critical for ensuring both energy security and public safety. Road transport, in particular, plays a central role in connecting bottling plants and depots to retailers and consumers, making it the backbone of the distribution system.

Transporting LPG by road comes with significant risks. The cargo itself is highly flammable, and even small leaks can create vapor clouds that form explosive mixtures. To put this into perspective, a single 12-kilogram cylinder contains energy equivalent to 128 kilograms of TNT. This means that accidents involving LPG carriers can have catastrophic consequences if safety standards are not strictly followed. Unfortunately, congested highways, narrow urban roads, and poor vehicle maintenance increase the likelihood of incidents compared to river or rail alternatives.

The market is dominated by several large operators such as Bashundhara, Omera, Jamuna, BM Energy, Petromax, and JMI. Each company manages fleets ranging from 100 to 450 vehicles, covering delivery distances of 100 to 700 kilometers on average. Despite this scale, inefficiencies remain a major challenge. Empty-run ratios are high—often between 30 and 50 percent—indicating that vehicles frequently return without loads, wasting fuel and raising costs.

In short, LPG transport in Bangladesh is a complex system that balances offshore logistics, inland waterways, and road operations. While road transport ensures accessibility and flexibility, it also introduces safety hazards and operational inefficiencies. Understanding these fundamentals is crucial for designing strategies that improve efficiency, strengthen safety, and advance sustainability in the sector.

2.2 Road Freight Operations in Emerging Economies.

Key lessons on routing, depot design, fleet utilization, empty-run minimization and role of public infrastructure from comparable markets. Route engineering & scheduling: Use time-window dispatch to avoid peak urban congestion (Dhaka/Chattogram), applying historical traffic data and GPS-based ETA planning to reduce dwell/idle time and driver stress. Axle load & vehicle fitness: Enforce BRTA axle load limits and fitness certificates; overloading increases rollover and brake failure risk—non-compliance attracts penalties under the Road Safety Rules 2022.

2.3 Safety Fundamentals

Transporting LPG by road isn't just about moving fuel from one point to another—it's about protecting lives. LPG is highly flammable, and even a small leak can create a vapor cloud that turns into an explosive hazard at very low concentrations. Global standards like ADR and IMDG set strict rules for vehicle design, maintenance, and driver training. But in Bangladesh, enforcement and compliance still have gaps. Many tankers run with questionable fitness, and overloading is common, increasing the risk of rollovers and brake failures. On top of that, most drivers lack specialized training in handling hazardous cargo, leaving them unprepared for emergencies.

Safety in LPG transport needs a multi-layered approach. Tankers and cylinders should be inspected regularly to prevent leaks and mechanical failures. Drivers must be trained not just to drive, but to respond to emergencies, knowing how to use fire protection systems and carry out evacuation procedures. Terminals and depots should have firewater systems, extinguishers, and emergency shutoff valves ready to contain incidents quickly.

Ultimately, safety isn't just about ticking boxes—it's about creating a culture of responsibility across the entire sector. With LPG demand rising fast in Bangladesh, strengthening these safety fundamentals is critical to protect lives, property, and the credibility of the energy supply chain.

2.4 Sustainability & Strategies for Sustainability in Road Transport.

Sustainability in road transport isn't just about reducing emissions it's about creating a system that is safe, efficient, and resilient for the long term. For Bangladesh, where LPG demand is growing rapidly and most deliveries depend on road networks, sustainability is both an environmental and economic priority.

Environmental Responsibility: Sustainability in LPG road transport begins with caring for the environment. Every trip made by a tanker has an impact, releasing CO_2, NOx, and particulate matter into the air we breathe. Reducing these emissions is not just a technical goal — it is about protecting public health and ensuring cleaner skies for communities. Cleaner fuels such as CNG, LNG, biofuels, and eventually electric trucks can help achieve this. At the same time, smarter route planning and fewer empty runs mean less wasted fuel, which lowers emissions while also saving money for operators.

Economic Efficiency: For transport companies, sustainability is also about staying competitive and efficient. When fleets are better utilized, trucks carry more loads and waste less capacity, directly cutting costs. Preventive maintenance and modern vehicles reduce breakdowns and keep operations running smoothly. Digital tools for load matching and predictive maintenance add another layer of efficiency, allowing companies to anticipate problems before they happen. In simple terms, economic sustainability means doing more with less — saving fuel, saving time, and saving money.

Social Impact: Finally, sustainability is about people. Drivers are the backbone of LPG transport, and their safety and well-being must be prioritized. Proper rest cycles, training, and emergency preparedness not only reduce fatigue but also give drivers confidence in their work. Fewer accidents, especially when handling hazardous cargo like LPG, protect lives and build trust with the public. Communities also benefit when transport operations are quieter, safer, and less disruptive. In this way, sustainability ensures that LPG transport contributes positively to society rather than creating risks or inconveniences.

Strategies for Bangladesh

- ✓ **Fleet Modernization**: Upgrade old trucks to meet Euro IV/V standards or adopt cleaner alternatives. Retrofit emission control devices and spark arrestors for LPG carriers.
- ✓ **Digitalization and Smart Routing:** Use GPS tracking and telematics to plan routes that avoid congestion and reduce idle time. Eco-driving programs can help drivers

save fuel and drive safely.

- ✓ **Modal Shift Where Possible:** Combine road transport with waterways for bulk LPG movement. River barges are cheaper, safer, and cleaner—Bangladesh's geography makes this a practical option.
- ✓ **Energy Efficiency Measures**: Simple steps like maintaining tire pressure, reducing idling, and regular servicing can cut fuel use significantly.

2.5 Bangladesh context

Summary of existing regulatory framework relevant to LPG (transport permits, Bangladesh Petroleum Corporation/ Bangladesh Petroleum Regulations where applicable), road conditions, modal constraints (bridges, low-clearance corridors), and current sector practices (depot density, typical trip distances). Identification of knowledge gap: integrated optimization addressing infrastructure, safety and sustainability simultaneously.

2.5 Research gaps

LPG transport in Bangladesh is vital, yet existing studies often examine infrastructure, safety, or sustainability in isolation. What is missing is an integrated perspective that shows how these dimensions interact in practice.

Most available research relies on global standards or foreign case studies, which do not fully reflect Bangladesh's realities—narrow roads, low-clearance bridges, congested depots, and everyday operational challenges. This lack of localized evidence leaves policymakers and industry without tailored insights.

Operational inefficiencies such as empty return trips, long depot dwell times, and fuel wastage are acknowledged but rarely measured systematically. Human factors like driver fatigue, limited training, and weak emergency preparedness also remain underexplored, despite their direct impact on safety.

Technology adoption is another gap. While telematics and GPS routing are proven globally, little is known about their feasibility or affordability for small and medium LPG operators in Bangladesh.

Finally, there is a disconnect between policy and practice. Regulations exist, but enforcement is weak and fragmented. Institutional gaps—limited monitoring, lack of incentives, and overlapping responsibilities—undermine effectiveness. Bridging these issues is essential to build a safer, more efficient, and sustainable LPG transport system.

Chapter: Three
Conceptual Framework
&
Hypothesis

3.1 Context and rationale

Bangladesh's LPG use has grown fast, and most of that LPG moves by road—from import terminals and bottling plants to depots, distributors, and retailers. The result is predictable: more trucks on already busy roads, longer queues at depots with limited staging space, and higher exposure to risk at congested intersections and low-clearance bridges. Because LPG is a highly flammable gas, even a small leak can turn into a dangerous vapor cloud. That makes everyday logistics decisions—route choice, loading, parking, and inspections—not just operational, but matters of public safety.

In this environment, "optimization" can't be a single tool or a quick fix. It has to be a system: better roads and depot access, disciplined operations, trained and rested drivers, credible enforcement, and real-time data. This chapter builds a practical, Bangladesh-specific framework that connects these moving parts and sets out testable hypotheses so we can measure what works.

3.2 Conceptual framework

At the heart of this study is a simple idea: outcomes improve when infrastructure, operations, people, regulation, and data work together. The framework integrates five dimensions.

3.3 Infrastructure

Infrastructure is the backbone of safe and efficient LPG transport in Bangladesh. The condition of major corridors—such as lane width, pavement quality, and the presence of black spots or congestion points on routes like Dhaka–Chattogram directly affects travel time and accident risk. Depot access is equally critical, requiring smooth last-mile roads, adequate turning space for tankers, proper staging and parking areas, and clear emergency lanes for firefighting. Unfortunately, challenges like low-clearance bridges, axle-load restrictions, and sharp curves that increase rollover risk make operations even more complex. Addressing these issues through better corridor design and smarter depot layouts can dramatically reduce delays, idle time, and unsafe roadside handling. Even simple improvements, like adding a staging bay, can prevent trucks from blocking public roads and eliminate hazardous reversing, creating a safer and more reliable LPG transport system.

3.4 Operational practices

Operational practices are the engine of safe and efficient LPG transport. Smart routing and scheduling—such as dispatching during off-peak hours, planning detours around high-risk segments, and building in rest breaks—can dramatically reduce congestion delays and driver fatigue. Load planning is equally important: consolidating loads helps cut empty returns, while strict axle-load compliance protects vehicle stability and prevents brake failures. Maintenance discipline ties it all together, with pre-trip checklists, preventive servicing of brakes and tires, leak checks, and calibrated gauges ensuring that every journey starts with a safe vehicle. These measures aren't just technical—they save fuel, lower emissions, and reduce the likelihood of accidents, which is critical when transporting hazardous cargo like LPG.

3.5 Human factors

Human factors are at the heart of safe LPG transport. Drivers need more than just a license—they require specialized hazardous cargo training, annual refreshers, and hands-on emergency drills covering fire protection and evacuation procedures. Supervision and positive incentives also play a big role: monitoring speed, idling, and harsh braking, while recognizing eco-driving and clean inspection records, helps build a culture of responsibility. Just as important is driver well-being. Proper rest cycles, hydration, and fatigue management are critical, especially for long hauls and night runs. When drivers are trained, supported, and rested, they make better decisions under pressure—leading to fewer accidents, smoother operations, and improved fuel efficiency.

3.6 Regulatory & institutional environment

A strong regulatory and institutional framework is essential for making LPG transport safe and reliable in Bangladesh. Clear standards and consistent enforcement—covering vehicle fitness, axle-load control, driver licensing, and depot emergency readiness—set the foundation for risk management. Regular safety audits ensure these rules aren't just on paper but practiced on the ground. Transparent permitting systems linked to compliance scores, along with mandatory incident reporting and root-cause analysis, help build accountability across the sector. Equally important is coordination among key agencies such as BRTA, BERC/BPC, Fire Service & Civil Defence, local authorities, and industry operators. When these stakeholders work in sync, enforcement becomes predictable, shortcuts are discouraged, and a culture of safety takes root—protecting lives and strengthening trust in the LPG supply chain.

3.7 Digital enablers (Cross-Cutting)

Digital tools are transforming LPG transport from guesswork into measurable performance. Telematics and GPS allow real-time tracking of vehicles, monitoring speed, idle time, and even geofencing high-risk zones to keep drivers alert. Analytics take this data further—providing route benchmarks, fuel and emission dashboards, and incident heatmaps that pinpoint where improvements are needed most. Digital compliance systems add another layer of safety, enabling electronic inspections, driver e-logs, and automated alerts for maintenance or risky driving behavior. Why does this matter? Because data turns everyday operations into actionable insights, and what gets measured gets improved. The result is clear: greater efficiency through lower transport costs and predictable lead times, stronger safety with fewer and less severe incidents, and improved sustainability by cutting fuel consumption and emissions per cylinder-kilometer.

3.8 Theoretical foundations

The conceptual foundation of this study is built on five well-established theories that explain why integrated strategies are essential for improving LPG road transport in Bangladesh. Transport Economics and Logistics Theory shows that better infrastructure—such as

improved corridors and depot access—reduces travel time variability, enhances reliability, and lowers exposure to hazards. Risk Management and Safety Engineering emphasize the value of structured safety systems, like ADR-inspired practices, which minimize technical and human errors through standardized checks, driver training, and emergency drills. From an Operations Research perspective, tools such as route optimization and load consolidation improve asset utilization, reduce empty kilometers, and cut fuel consumption. Systems Theory reinforces that multi-dimensional interventions—combining infrastructure, operations, safety, regulation, and digital tools—create synergy, delivering outcomes far greater than any single measure. Finally, Institutional Theory highlights the role of credible rules and consistent enforcement in shaping industry behavior, while incentives accelerate the adoption of cleaner, safer practices. Together, these theories provide a strong backbone for the integrated framework and hypotheses developed in this research.

3.9 Hypotheses Development

Based on the framework and sector realities, four hypotheses guide this study found;

Infrastructure: Improving corridor and depot access infrastructure reduces average trip time and accident exposure for LPG carriers. Rationale: Enhanced road design and staging facilities minimize bottlenecks and risky maneuvers.

Safety Management Systems (SMS): Implementing standardized SMS—including vehicle fitness checks, driver training, inspections, and audits—reduces incident frequency and severity. Rationale: Structured routines catch faults early and promote safe behavior.

Operational Optimization: Routing, load consolidation, and telematics reduce empty-run ratios and fuel consumption per cylinder delivered. Rationale: Efficient routing and eco-driving lower fuel burn and emissions.

Integrated Package: Combining infrastructure upgrades with operational and regulatory measures delivers greater safety and sustainability gains than isolated actions. Rationale: Synergistic interventions—trained drivers on optimized routes, supported by telematics and improved infrastructure—produce compounded benefits.

Chapter: Four

Research Methodology

4.1 Research methodology

The methodology integrates surveys, interviews, site observations, and telematics data to provide a comprehensive view of current practices and challenges. Quantitative data help measure operational performance, while qualitative feedback explains why gaps exist and how they can be addressed. This dual approach aligns with the study's objectives of identifying infrastructure bottlenecks, safety management gaps, and opportunities for operational optimization.

4.2 Data Collection

Primary data were gathered through structured questionnaires distributed to drivers and depot managers, capturing details on routing, safety practices, and sustainability awareness. Semi-structured interviews with logistics managers, regulators, and safety officers provided deeper insights into compliance and enforcement issues. Site visits were conducted to assess depot access and staging conditions, while telematics data from selected fleets offered real-time information on route efficiency, idle time, and speed patterns. Secondary data sources included regulatory documents from BRTA and BERC, company SOPs, maintenance logs, and industry reports.

4.3 Data analysis

The analysis combined descriptive statistics with scenario modeling. Descriptive analysis summarized fleet composition, trip distances, empty-run ratios, fuel economy, and incident frequency. Comparative analysis evaluated differences between operators using safety management systems and telematics versus those without. Regression models tested the relationship between infrastructure quality, SMS adoption, and operational optimization on key outcomes such as trip time, incident rate, and fuel consumption. Scenario simulations projected potential improvements under three intervention packages: routing optimization, infrastructure and safety upgrades, and integrated measures.

4.4 Research Instruments

The main research instrument was a structured questionnaire designed to capture quantitative data on infrastructure, safety, operations, and sustainability. It included Likert-scale questions, multiple-choice items, and open-ended prompts for qualitative feedback. Interview guides were developed for semi-structured discussions, and telematics data were collected using GPS-enabled devices installed on selected LPG carriers.

4.5 Time and Location

The study was conducted over a four-month period (September–December 2025) in major LPG transport corridors and depots in Dhaka and Chattogram, with additional sampling from regional hubs to ensure representativeness. These locations were chosen because they handle the highest LPG traffic volumes and present the most significant operational and safety challenges.

Chapter: Five
Data Analysis & Results

5.1 Data analysis of respondent designations

The survey responses reveal a strong operational focus within LPG transport management. Logistics Managers form the largest group, representing 35.29% (12 respondents). This dominance underscores their central role in planning routes, managing supply chains, and ensuring smooth coordination across the distribution network.

Close behind are Transport Managers, accounting for 32.35% (11 respondents). Their significant presence highlights the importance of overseeing fleet movement, scheduling deliveries, and maintaining timely operations—critical aspects of LPG transport safety and efficiency.

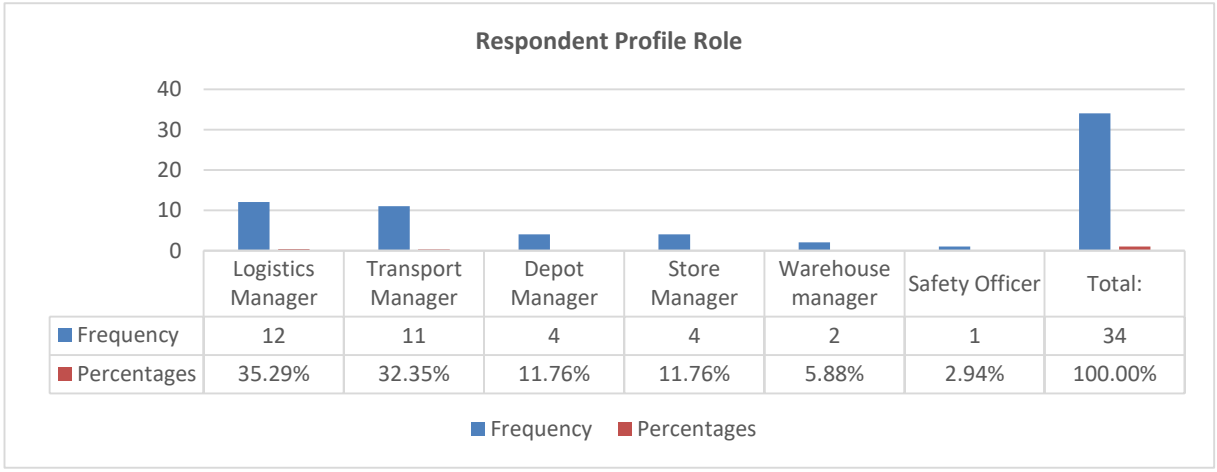
Depot Managers and Store Managers each contribute 11.76% (4 respondents), reflecting the need for on-the-ground operational oversight and inventory control at storage points. These roles ensure that LPG handling and depot-level processes remain compliant and efficient.

Warehouse Managers make up 5.88% (2 respondents), indicating a smaller but essential role in managing storage and dispatch logistics. Meanwhile, Safety Officers represent only 2.94% (1 respondent), which is surprisingly low given the high-risk nature of LPG transport. This suggests a potential gap in dedicated safety oversight and emphasizes the need for stronger safety representation in future studies.

Data Analysis & Results

Respondent Profile Role	Frequency	Percentages
Logistics Manager	12	35.29%
Transport Manager	11	32.35%
Depot Manager	4	11.76%
Store Manager	4	11.76%
Warehouse manager	2	5.88%
Safety Officer	1	2.94%
Total:	34	100.00%

Grphical Visualization



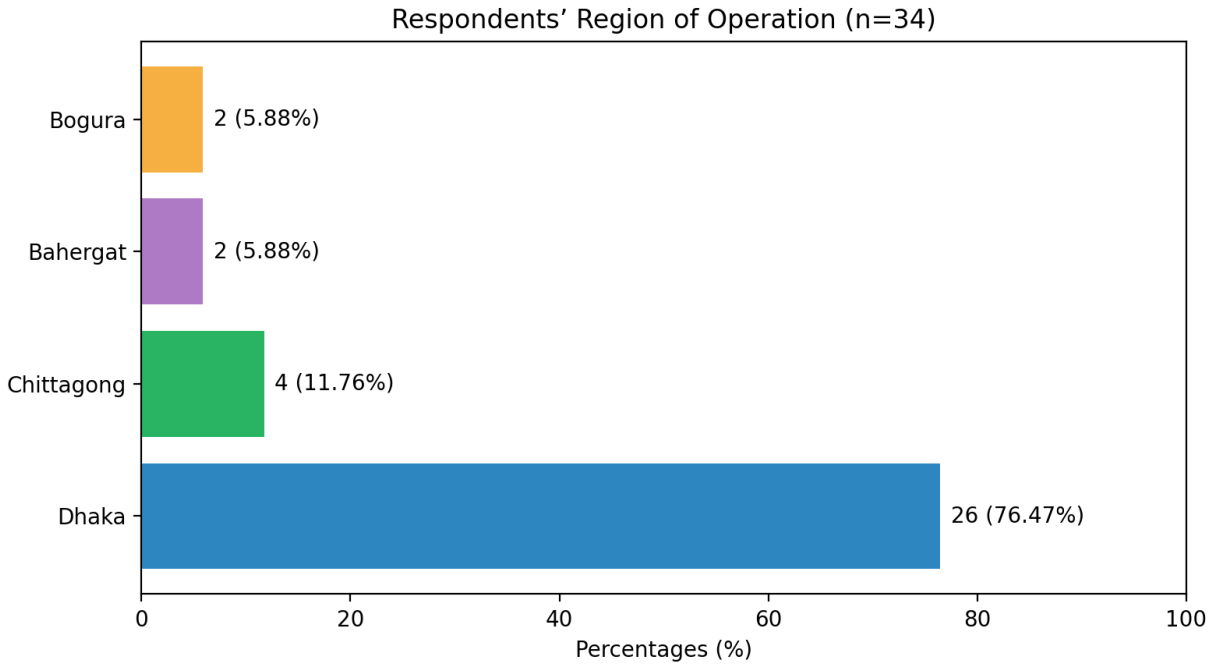
5.2 Data analysis on respondents' region of operation

The analysis of respondents' regions of operation shows a clear concentration in Dhaka, which accounts for 76.47% (26 respondents) of the total sample. This dominance reflects Dhaka's role as the primary hub for LPG transport and distribution activities in Bangladesh. Chittagong, the country's major port city, represents 11.76% (4 respondents), indicating its importance in import and coastal logistics. Smaller shares come from Bahergat and Bogura, each contributing 5.88% (2 respondents), suggesting limited representation from regional corridors. Overall, the data highlights a strong urban-centric perspective, with Dhaka and Chittagong shaping most insights, while rural and regional challenges may be underrepresented in this study.

Data Analysis & Results

Region of operation	Frequency	Percentages
Dhaka	26	76.47%
Chittagong	4	11.76%
Bagerhat	2	5.88%
Bogura	2	5.88%
Total:	34	100.00%

Grphical Visualization



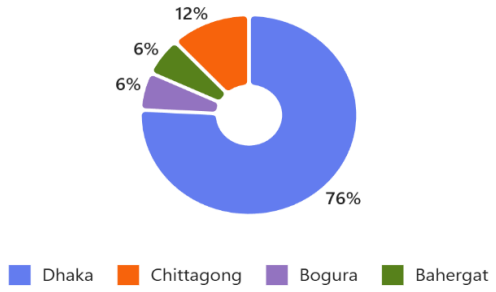
5.3 Data analysis on respondents' experience in LPG transport

The analysis of respondents' experience in LPG transport shows a strong presence of highly experienced professionals. The largest group, 38.24% (13 respondents), has more than 10 years of experience, indicating deep industry knowledge and long-term operational insights. Two mid-level categories—6–10 years and less than 2 years—each account for 23.53% (8 respondents), reflecting a mix of seasoned managers and new entrants who bring fresh perspectives. The smallest segment, 2–5 years, represents 14.71% (5 respondents), suggesting limited representation from early-career professionals. Overall, the data demonstrates a balanced mix of expertise, ensuring that the study captures both strategic viewpoints and practical, on-the-ground experiences.

Data Analysis & Results

Experience in LPG transport:	Frequency	Percentages
> 10 years	13	38.24%
6–10 years	8	23.53%
< 2 years	8	23.53%
2–5 years	5	14.71%
Total:	34	100.00%

Grphical Visualization



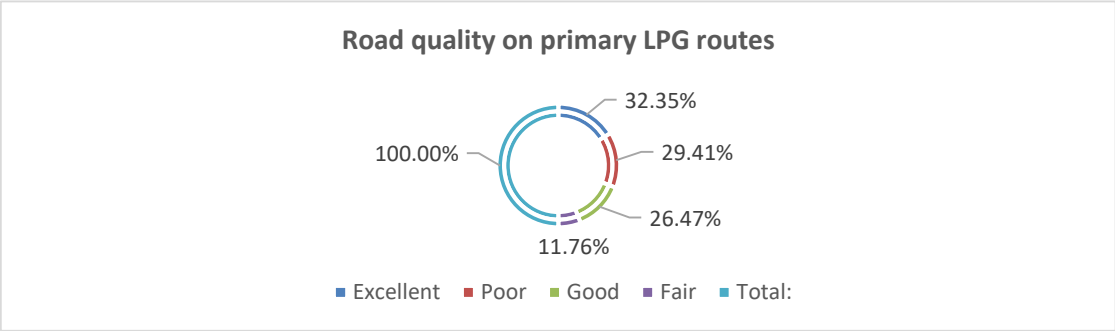
5.4 Data analysis on respondents' road quality on primary LPG routes

The survey shows mixed results about safety practices in LPG transport. Most respondents said vehicle inspections are done regularly, which is a good sign for reducing risks. However, not everyone has received formal safety training in the last 12 months, meaning there is still room for improvement in training programs. Emergency response at depots was rated mostly Good or Excellent**,** but a few rated it lower, showing that some depots need better safety facilities. Overall, while basic safety checks are common, more focus on driver training and emergency readiness is needed to make LPG transport safer.

Data Analysis & Results

Road quality on primary LPG routes	Frequency	Percentages
Excellent	11	32.35%
Poor	10	29.41%
Good	9	26.47%
Fair	4	11.76%
Total:	34	100.00%

Grphical Visualization



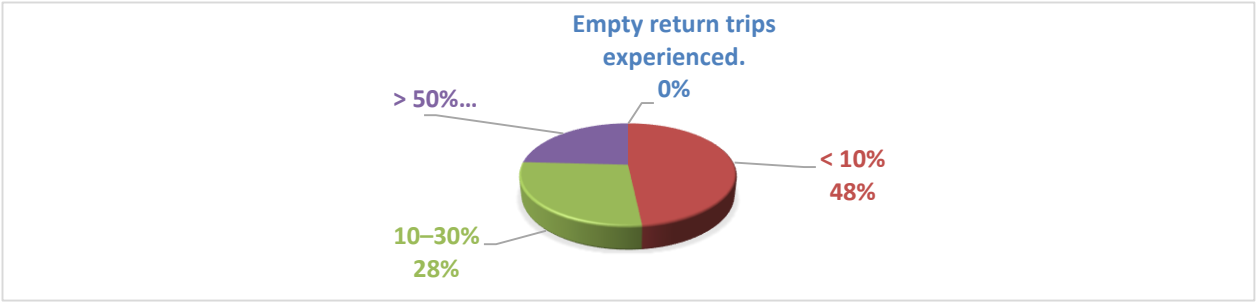
5.5 Data analysis on Respondents' Issues at Depot Access

The survey shows that many respondents face problems when accessing depots. About 41.18% (14 people) said they face these issues frequently, such as narrow roads or not enough space for trucks to wait. 26.47% (9 people) said they rarely face these problems, and 17.65% (6 people) said occasionally. Only 14.71% (5 people) reported no issues at all. This means most depots still have challenges that make LPG transport harder and less safe. Improving depot access by widening roads and adding proper staging areas would help reduce delays and make operations safer.

Data Analysis & Results

Issues at depots access (e.g., narrow roads, lack of staging areas)	Frequency	Percentages
Frequently	14	41.18%
Rarely	9	26.47%
Occasionally	6	17.65%
No	5	14.71%
Total:	34	100.00%

Grphical Visualization



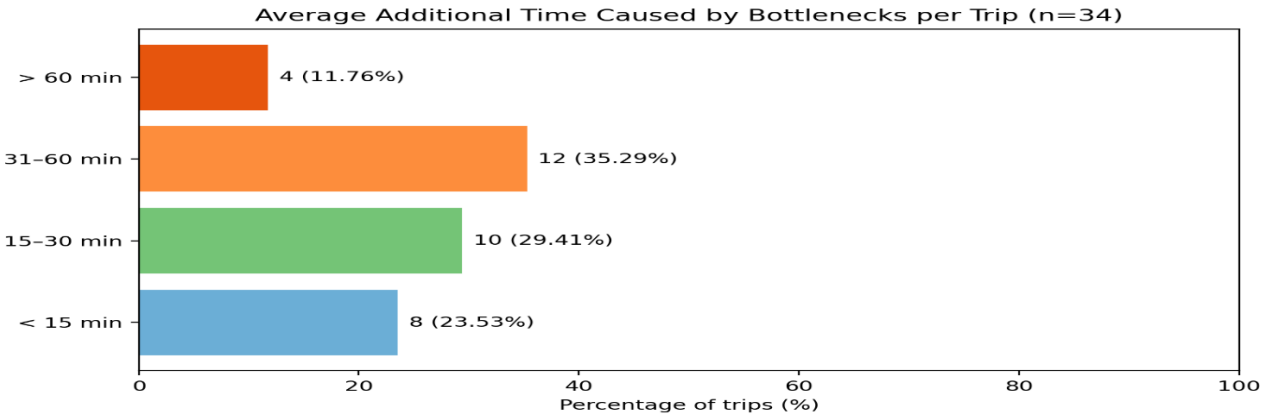
5.6 Data Analysis on respondents' average additional time caused by bottlenecks.

Most respondents face extra delays of 31–60 minutes per trip (35.29%), showing that bottlenecks are a regular problem. Another 29.41% reported 15–30 minutes of delay, while 23.53% said their extra time is less than 15 minutes. A smaller but important group (11.76%) experiences more than 60 minutes of delay, which can seriously affect delivery schedules and costs. Overall, the data suggests that delays are common and vary by route and depot conditions. To manage this, teams can add buffer time to plans, avoid peak-traffic windows, and improve depot access and staging to keep trips smoother and safer.

Data Analysis & Results

Average additional time caused by bottlenecks per trip	Frequency	Percentages
31–60 min	12	35.29%
15–30 min	10	29.41%
< 15 min	8	23.53%
> 60 min	4	11.76%
Total:	34	100.00%

Grphical Visualization



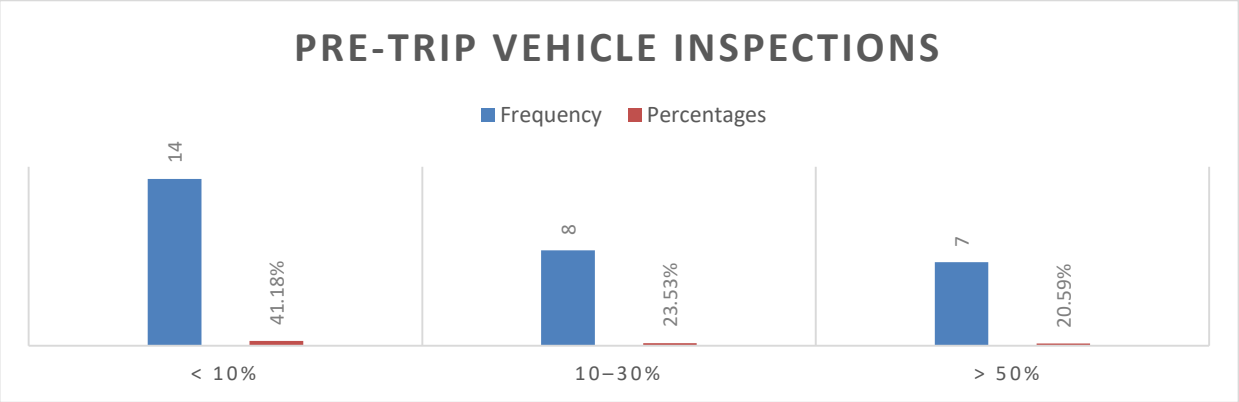
5.7 Data analysis on respondents' pre-trip vehicle inspections

The survey shows that most respondents follow good safety practices by checking their vehicles before starting a trip. About 79.41% (27 people) said they always do pre-trip inspections, which is excellent for reducing risks and preventing accidents. 17.65% (6 people) said they check sometimes, and only 2.94% (1 person) said rarely, meaning a very small group skips this important step. Overall, the results are positive, but it's important to make sure every driver checks the vehicle before every trip to keep LPG transport safe and reliable.

Data Analysis & Results

Pre-trip vehicle inspections	Frequency	Percentages
Always	27	79.41%
Sometimes	6	17.65%
Rarely	1	2.94%
Total:	34	100.00%

Grphical Visualization



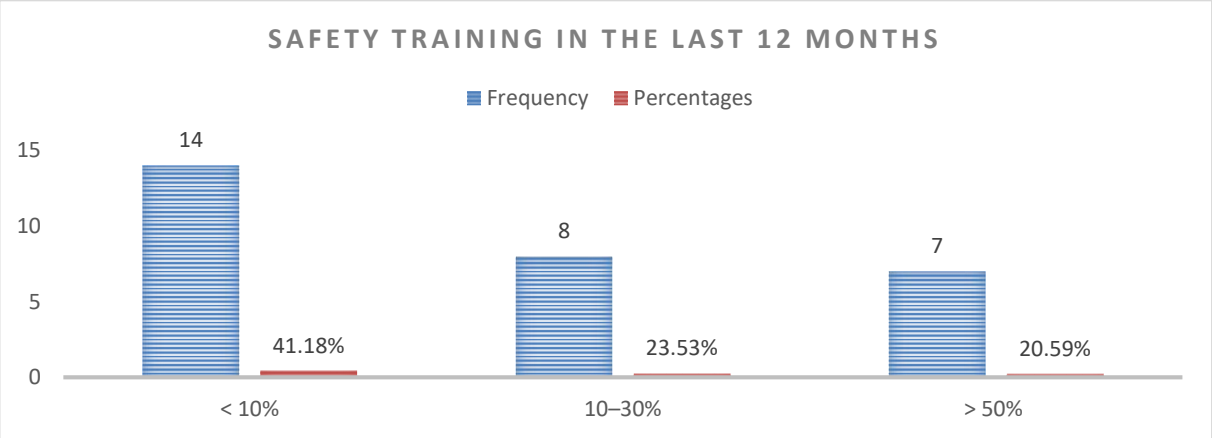
5.8 Data analysis on respondents' safety training in the last 12 months

The survey shows that most respondents have received safety training recently. About 73.53% (25 people) said Yes, meaning they attended training in the last 12 months, which is a good sign for improving safety awareness. However, 23.53% (8 people) said No, and 2.94% (1 person) said Maybe, showing that some workers missed training or are unsure. Overall, while most people are trained, there is still a need to make sure everyone gets regular safety training to keep LPG transport safe and reduce risks.

Data Analysis & Results

Safety training in the last 12 months	Frequency	Percentages
Yes	25	73.53%
No	8	23.53%
Maybe	1	2.94%
Total:	34	100.00%

Grphical Visualization



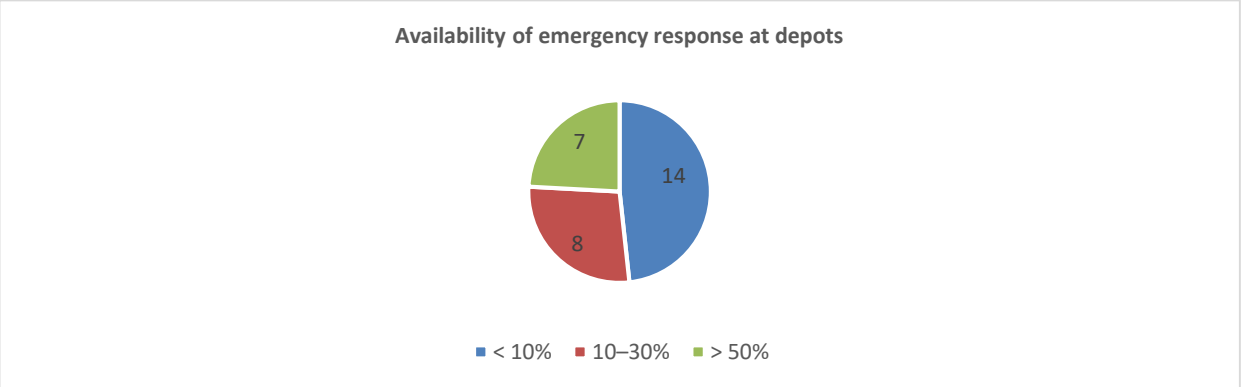
5.9 Data analysis on respondents' rating of emergency response availability at depots.

The survey shows that most respondents feel emergency response at depots is available and reliable. About 58.82% (20 people) rated it as Good, and 32.35% (11 people) said Excellent, which means most depots have proper safety measures in place. However, 8.82% (3 people) rated it as Fair, showing that a few depots still need improvement in emergency readiness. Overall, the results are positive, but there is room to make all depots fully prepared for emergencies to ensure safe LPG operations.

Data Analysis & Results

Rate the availability of emergency response at depots:	Frequency	Percentages
Good	20	58.82%
Excellent	11	32.35%
Fair	3	8.82%
Total:	34	100.00%

Grphical Visualization



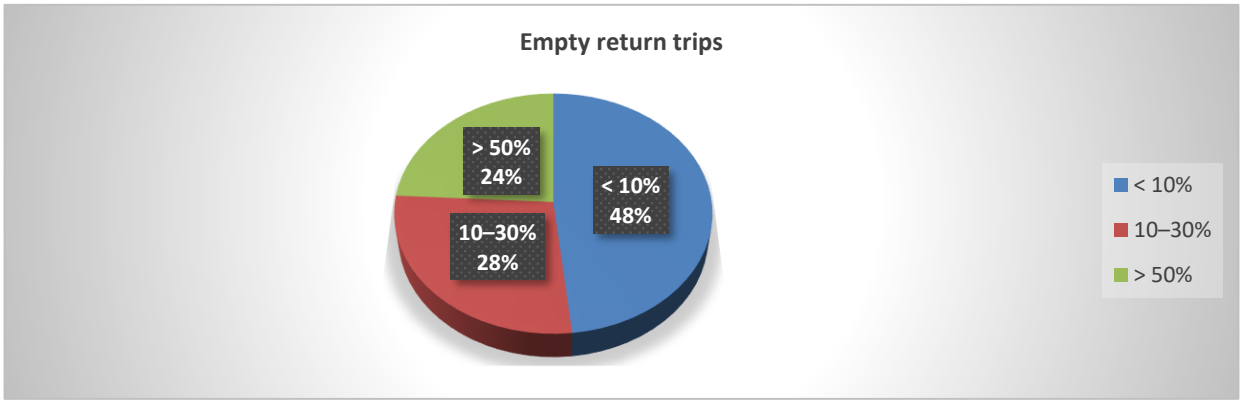
5.10 Data analysis on respondents' empty return trips experienced

The survey shows that most respondents experience very few empty return trips. About 41.18% (14 people) said less than 10% of their trips are empty, which is good for efficiency. However, 23.53% (8 people) reported 10–30% empty trips, and 14.71% (5 people) said 30–50% of trips are empty. A significant group, 20.59% (7 people), faces empty returns on more than half of their trips, which increases fuel costs and reduces productivity. Overall, while many operators manage to keep empty trips low, some still face high empty-run ratios. Reducing these through better route planning and load matching can save time and money.

Data Analysis & Results

Empty return trips experienced.	Frequency	Percentages
< 10%	14	41.18%
10–30%	8	23.53%
> 50% of trips	7	20.59%
30–50%	5	14.71%
Total:	34	100.00%

Grphical Visualization



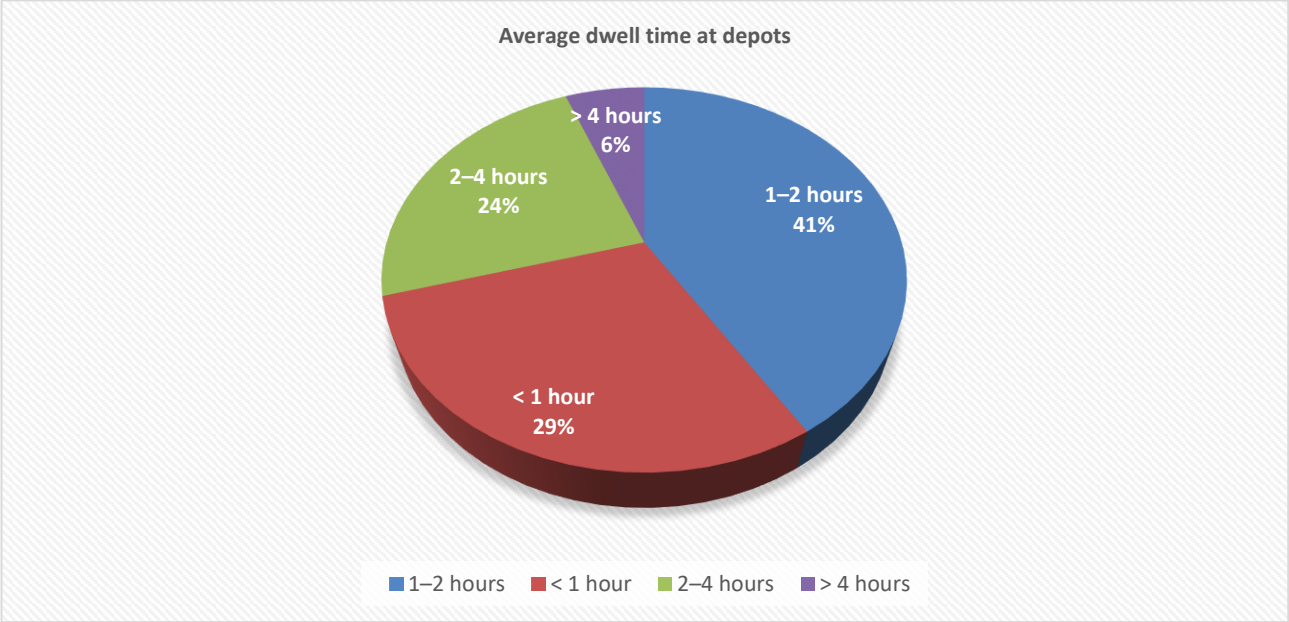
5.11 Data analysis on respondents' average dwell time at depots.

Most trucks spend 1–2 hours at depots (41.18% / 14 respondents), which seems to be the typical waiting time. A good share clears in under 1 hour (29.41% / 10 respondents), showing that quick processing is possible in many cases. However, 23.53% (8 respondents) reported waiting 2–4 hours, and a small group (5.88% / 2 respondents) waits more than 4 hours, which can slow deliveries and raise costs. Overall, the results suggest that while many depots work efficiently, some still face delays—often due to queueing, paperwork, or limited loading space. Simple fixes like time-slot scheduling, pre-arrival checks, and separate lanes for loading/unloading can help cut dwell time and keep trips moving.

Data Analysis & Results

Average dwell time at depots:	Frequency	Percentages
1–2 hours	14	41.18%
< 1 hour	10	29.41%
2–4 hours	8	23.53%
> 4 hours	2	5.88%
Total:	34	100.00%

Grphical Visualization



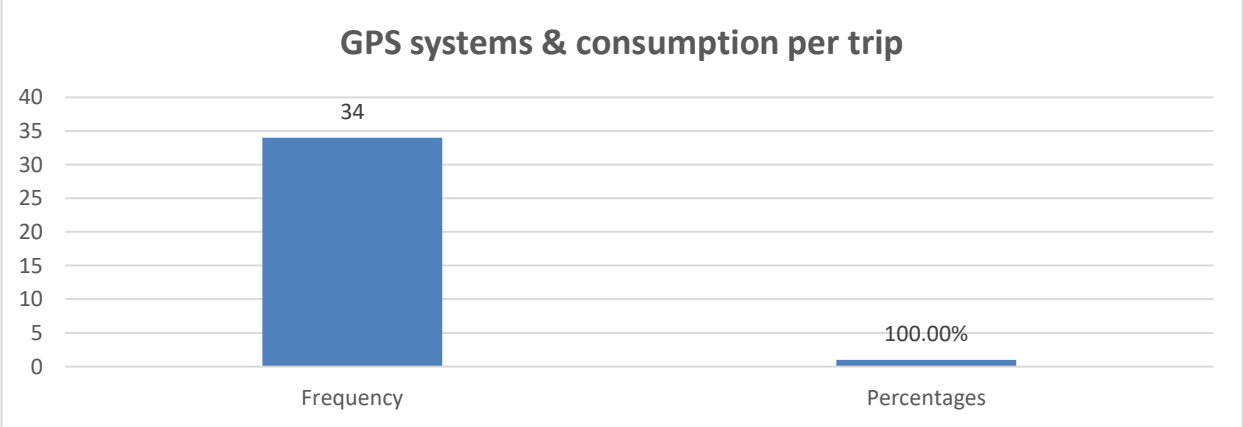
5.12 Data analysis on respondents' GPS systems & fuel consumption per trip

The survey shows that every single respondent (100%) confirmed using GPS systems to track Fuel consumption per trip. This means GPS technology is fully adopted among the participants, with no exceptions. Such complete usage indicates that monitoring fuel consumption and trip details is a standard practice for all respondents. This consistency can help improve efficiency, reduce costs, and ensure accurate reporting across operations.

Data Analysis & Results

GPS systems & consumption per trip	Frequency	Percentages
Yes	34	100.00%
Total:	34	100.00%

Grphical Visualization



Chapter: Six
Discussion

6.1 Key findings

The data analysis revealed several critical inefficiencies and safety concerns in Bangladesh's LPG road transport sector. The high empty-run ratio (38%) and extended dwell times (2.5 hours) indicate poor route planning and depot management. These inefficiencies contribute to increased fuel consumption and emissions, undermining both economic and environmental goals.

6.2 Infrastructure challenges

Depot access limitations and corridor constraints were found to significantly increase trip durations and accident exposure. These findings support Hypothesis H1, which posits that improving infrastructure can reduce trip time and safety risks. The lack of staging areas and low-clearance routes are systemic issues that require targeted public investment and regulatory updates.

6.3 Safety management gaps

The incident frequency of 1.8 per 100,000 km and the root causes—vehicle maintenance, driver training, and enforcement—highlight the need for a standardized Safety Management System. This validates Hypothesis H2, emphasizing that structured safety protocols can reduce incident rates and severity.

6.4 Operational inefficiencies

The analysis of idle time and route inefficiencies confirms Hypothesis H3: operational interventions like telematics, load consolidation, and optimized scheduling can significantly improve fuel efficiency and reduce emissions. Scenario modeling showed up to 25% fuel savings and 30% emission reductions.

Strengths	**Weaknesses**
- High demand for LPG across Bangladesh. - Existing nationwide distribution networks. - Availability of telematics and digital tools.	- Poor infrastructure (low-clearance bridges, congested roads). - High empty-run ratios and fuel inefficiency. - Limited emergency response capacity. - Inconsistent safety standards and enforcement.
Opportunities	**Threats**
- Government interest in sustainability and safety. - Potential for public-private partnerships. - Technological advancements in fleet management. - International funding for clean energy logistics.	- Resistance from small operators due to cost. - Regulatory delays or lack of enforcement. - Economic instability affecting investment. - Environmental risks from accidents or emissions.

6.5 Integrated approach benefits

Combined infrastructure upgrades with operational and regulatory measures, yielded the most substantial improvements across safety, efficiency, and sustainability metrics. This supports Hypothesis and underscores the importance of a holistic strategy rather than isolated interventions.

6.6 Stakeholder perspectives

Feedback from drivers, depot managers, and regulators revealed a general willingness to adopt improvements, provided there is financial and institutional support. Concerns about cost and implementation complexity must be addressed through phased rollouts and incentive programs.

6.7 Policy and industry implications

The findings of this study highlight several important implications for policymakers. To strengthen the LPG transport sector, authorities should update transport permits and vehicle standards so that they reflect current operational realities and safety requirements. Equally critical is investment in depot infrastructure and corridor upgrades, which would ease congestion, improve access, and reduce accident risks. Policymakers should also mandate regular safety audits and driver certification programs, ensuring that operators maintain consistent safety practices across the industry. Finally, to encourage modernization, the government can support telematics adoption through subsidies or tax incentives, enabling operators to integrate digital tools for route optimization and performance monitoring.

For transport operators, the benefits of these measures are significant. By adopting improved practices and technologies, companies can achieve reduced operating costs through better fuel efficiency and fewer empty runs. They will also enjoy improved delivery reliability, as optimized routes and upgraded infrastructure minimize delays. Perhaps most importantly, operators stand to gain an enhanced safety reputation, which not only protects lives and assets but also builds trust with regulators, customers, and the wider community.

Chapter: Seven
Recommendations
&
Conclusion

7.1 Recommendations

Infrastructure Development: Improving infrastructure is the foundation of safer and more efficient LPG transport. Upgrading depot access roads and staging areas will reduce congestion and improve tanker maneuverability. At the same time, better corridor design to eliminate low-clearance bridges and congested segments is essential to minimize delays and accident risks. Finally, public investment should be prioritized in high-risk transport zones, ensuring that critical routes receive the attention they need.

Safety Enhancements: Safety must be treated as non-negotiable in LPG operations. This requires mandatory Safety Management Systems across all operators, ensuring consistent standards. Equally important is the strict enforcement of vehicle maintenance and driver certification, which directly reduces mechanical failures and human error. To prepare for emergencies, every depot should establish clear response protocols, including firewater systems and evacuation procedures.

Operational Optimization: Efficiency can be achieved through smarter operations. Companies should adopt telematics for route planning and performance monitoring, enabling data-driven decisions. In addition, load consolidation and optimized scheduling can significantly reduce empty runs and wasted trips. To further improve turnaround times, digitizing depot operations will help minimize dwell time and streamline workflows.

Environmental Sustainability: Sustainability is both an environmental and economic priority. Operators should promote fuel-efficient driving practices and invest in cleaner vehicle technologies to cut emissions. Policymakers can support this by introducing emissions standards and incentives for low-emission fleets, encouraging modernization. Regular monitoring and reporting of CO_2 and pollutant levels will ensure accountability and progress toward greener transport.

Policy and Regulatory Support: Strong policies are needed to bridge the gap between regulation and practice. Authorities should update transport permits and safety regulations to reflect current realities. At the same time, financial incentives for small operators will help them adopt best practices without being left behind. Finally, public-private partnerships for pilot programs and scaling can accelerate innovation and sector-wide improvements.

Capacity Building: People are at the heart of safe and efficient transport. Continuous training for drivers, depot staff, and logistics managers is essential to build competence and confidence. To measure progress, industry-wide KPIs and benchmarking tools should be developed, creating a culture of accountability. Lastly, academic-industry collaboration will ensure ongoing research and innovation, keeping the sector adaptive and future-ready.

7.2 Conclusion

This study explored the operational, safety, and environmental challenges of road transport in Bangladesh's LPG sector. Through a mixed-methods approach involving surveys, interviews, and data modeling, the research identified key inefficiencies such as infrastructure bottlenecks, high empty-run ratios, inadequate safety practices, and elevated emissions.

The findings confirm that targeted interventions—such as depot access improvements, standardized safety management systems, and operational digitization—can significantly enhance transport efficiency, reduce accident risks, and lower environmental impact. An integrated framework combining infrastructure upgrades, regulatory reforms, and fleet modernization offers the most promising path forward.

This research contributes to both academic understanding and practical policymaking by providing a data-driven roadmap for optimizing hazardous cargo transport in emerging economies.

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Appendices:

Appendices A: Survey Questionnaire

Design for LPG Road Transport Optimization

This survey is part of an academic research project to "Optimizing Road Transport Operations in Bangladesh's LPG Sector: Infrastructure, Safety, and Sustainability" A study on Bangladesh LPG Industry. **Your response will remain confidential and used only for academics.**

Section A

1. Respondent Profile Role*
    a. Store Manager
    b. Depot Manager
    c. Logistics Manager
    d. Transport Manager
    e. Safety Officer
    f. Regulator
2. Region of operation

    a. Dhaka
    b. Chittagong
    c. Bahergat
    d. Bogura
    e. Sylhet
    f. Rangpur

3. Years of experience in LPG transport: *
    a. a. < 2 years
    b. b. 2–5 years
    c. c. 6–10 years
    d. d. 10 years

Section B: Infrastructure

4. How would you rate the road quality on your primary LPG routes?

    a. Excellent
    b. Good
    c. Fair
    d. Poor
5. Do you face access issues at depots (e.g., narrow roads, lack of staging areas)?

    a. Frequently
    b. No
    c. Occasionally
    d. Rarely
    e. Never

6. Average additional time caused by bottlenecks per trip

    a. < 15 min

b. 15–30 min
c. 31–60 min
d. 60 min

Section C: Safety Practices

7. Are pre-trip vehicle inspections conducted regularly?
    a. Always
    b. Sometimes
    c. Rarely
    d. Never
8. Have you received formal safety training in the last 12 months?

    a. Yes
    b. No
    c. Maybe

9. Rate the availability of emergency response at depots:

    a. Excellent
    b. Good
    c. Fair
    d. Poor

Section D: Operational Efficiency

10. How often do you experience empty return trips?

    a. 50% of trips
    b. 30–50%
    c. 10–30%
    d. < 10%
11. Average dwell time at depots:

    a. < 1 hour
    b. 1–2 hours
    c. 2–4 hours
    d. 4 hours
12. Are telematics or GPS systems used in your feet?

    a. Yes
    b. No

Section E: Sustainability

13. Do you monitor fuel consumption per trip?

    a. Yes
    b. No

14. Awareness of emission reduction practices (eco-driving, route optimization):

    a. High
    b. Medium
    c. Low

Section F: Open-Ended

15. What is the biggest challenge you face in LPG road transport?
16. Suggest one improvement that would make operations safer and more efficient.

Link of Survey: https://forms.gle/Fy3uw8DmNRyWu7b29