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DEVELOPING A ROAD FREIGHT TRANSPORT PERFORMANCE MEASUREMENT SYSTEM TO DRIVE SUSTAINABILITY

AN EMPIRICAL STUDY OF EGYPTIAN ROAD FREIGHT TRANSPORT COMPANIES

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Copyright Statement

This thesis is dedicated to my father. I deeply miss him and wish he could celebrate the end of my PhD journey with me.

Rest in peace my Soul-mate.

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Developing a Road Freight Transport Performance Measurement System through the Lens of Sustainability: An Empirical Study on Egyptian Road Freight Transport Companies

Abstract

While several road freight performance measurement systems have been developed, only a limited number of quantified performance measurement frameworks encompassing diverse sets of performance metrics from multiple sustainable perspectives are available on a technological platform. These sets of metrics could be integrated as crucial performance indicators for assessing the operational performance of various road freight transport companies. These indicators include fuel efficiency, trip duration, vehicle loading, and cargo capacity. The objective of this research is to construct a conceptual road freight performance measurement framework that comprehensively incorporates performance elements from sustainable viewpoints (economic, environmental, and social), leveraging technology to measure the performance of road freight transport companies. This proposed framework aims to aid these companies in gauging their performance using technology, thus enhancing their operations towards sustainability.

Within the road freight transport sector, several challenges exist, with congestion, road infrastructure maintenance, and driver training and qualifications being particularly pressing issues. The developed performance measurement framework offers the means for companies to evaluate the effects of technology integration on vehicles and overall performance. This allows companies to measure their performance from an operational standpoint rather than solely a strategic one, thereby identifying areas requiring improvement. Egypt was chosen as the empirical study location due to its relatively low level of technological integration within its road freight sector.

This thesis employs an explanatory mixed methods approach, encompassing four distinct phases. The first phase entails a review to formulate the proposed theoretical performance measurement framework. Subsequently, the second phase involves conducting semi-structured interviews using a Delphi method to both develop a conceptual performance measurement framework and explore the present state of Egypt's road freight transport sector. Following this, the third phase encompasses surveys based on the results derived from Delphi analysis, involving diverse participants from the road freight transport industry. The aim is to validate the developed performance measurement framework through an empirical study conducted in Egypt. Lastly, the fourth phase centres around organizing focus groups involving stakeholders within road freight transport companies. The goal here is to propose a roadmap for implementing the developed road freight transport performance measurement framework within the Egyptian context.

The primary theoretical contribution of this research is the development of a road freight transport performance measurement framework that integrates the three sustainability dimensions with technology. Additionally, this study offers practical guidance for the application of the developed framework in various countries and contexts. From a practical standpoint, this research aids road freight transport managers in evaluating their operational performance, thereby identifying challenges, devising action plans, and making informed decisions to mitigate these issues and enhance sustainability-oriented performance. Ultimately, the developed road freight transport performance measurement framework is poised to promote performance measurement aligned with technology, fostering progress towards achieving the sustainable development goals by 2030.

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List of Abbreviations

Technological apps	Technological Applications
KPIs	Key Performance Indicators
GPS	Global Positioning System
GHG	Green House Gas Emissions
PMS	Performance Measurement System
JIT	Just in Time
ITSS	International Transport Systems
OBOR	One Belt One Road
IRR	Internet Routing Registry
BRTAS	Bilateral Road Transport Agreements
ICT	Information and Communication Transport
RTA	Road Transport Authority
IRU	International Road Union
GARBLT	The General Authority for Roads, Bridges and Land Transport
SPSS	Statistical Package for the Social Sciences
COVID-19	Corona Virus Disease 2019

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CHAPTER ONE: INTRODUCTION

1.1 Background

Freight transport plays a significant role in shaping countries' economies and activities, as it facilitates the movement of goods between origins and destinations, contributing to economic development (UNCTAD, 2017). With the rise in population numbers, the demand for freight transport has grown accordingly. Road transport stands out as the predominant mode for cargo movement in numerous countries worldwide. However, this prevalence has brought about notable adverse effects, including air and noise pollution, traffic congestion, and increased rates of accidents, all of which impact both the environment and surrounding areas (Arbués et al., 2016).

Over the past decade, several countries, particularly in Europe, have endeavoured to shift their transportation modes away from road transport towards environmentally friendly inland alternatives. Yet, a multitude of challenges persist, impeding their progress (Choudhary et al., 2020). This is due to the requirement for various actions, including the enforcement of new regulations, infrastructure development, and the encouragement of manufacturers and companies to embrace non-road transport options. Furthermore, certain countries like Belgium, Italy, and Egypt rely heavily on road-based cargo transport, with Belgium, for example, relying on roads for 81%, railways for 9%, and inland waterways for 10% of its transportation needs (Meers et al., 2015).

Research indicates that specific road freight transport companies, particularly those in the Serbian and Egyptian markets, lack the necessary service quality to meet customer expectations, and they lack effective means to measure the quality of service provided (El Husseiny et al., 2017; Kilibarda et al., 2016). Consequently, these companies struggle to identify issues and enhance their service quality. Ideally, road freight transport companies should possess the capability to assess their performance, pinpoint challenges, and work towards their improvement (Kilibarda et al., 2016).

The dependency on road transport has increased significantly in terms of moving cargo from origin to destination, but this reliance has introduced various sustainability challenges, spanning environmental, social, and economic aspects (Rai et al., 2017). These challenges encompass emissions of greenhouse gases, air and noise pollution, safety concerns, loading/unloading difficulties, and congestion (Ambrosino et al., 2019). Consequently, quantifying the actions and activities of road freight transport companies, as well as embracing innovative solutions such as city logistics (linked to physical internet and road infrastructure) aimed at enhancing truck tracking and safety, would contribute significantly to sustainable performance improvement (Choudhary et al., 2020).

Numerous problems afflict the road freight transport sector in various countries, including Belgium, India, and the USA, with congestion, road infrastructure upkeep, truck driver shortages in advanced economies, and driver training issues in emerging markets emerging as the most prominent challenges (Elgazar et al., 2023; Pathak et al., 2019; Kumar et al., 2019). By alleviating these issues, which have direct economic,

environmental, and social impacts, road freight transport companies could enhance their performance. To mitigate these challenges, freight businesses aim to implement performance measurement systems that monitor their operations (Merchan et al., 2019; Li et al., 2019; ERTRAC Report, 2019; Mittal et al., 2018; McKinnon et al., 2012).

Past research indicates that the implementation of technology apps has mitigated certain road freight transport challenges and bolstered overall organizational performance (Elgazar et al., 2023; Carlan et al., 2019; Mehdizadeh et al., 2019). Through comprehensive measurement within the performance measurement system, companies can assess the impact of technology on their overall performance (Zavalko, 2018; Tobogu et al., 2018).

While diverse performance measurement approaches exist for assessing road freight transport companies' performance, these measurements have yet to be consolidated into an integrated performance measurement system (Li et al., 2017; Campos et al., 2019). Consequently, a need persists for a road freight transport performance measurement framework that encompasses various performance facets from a sustainability perspective (Kumar et al., 2019). Additionally, the adoption of technologies and innovative practices within road freight transport performance measurement, addressing economic, environmental, and social dimensions, remains relatively low. Ultimately, these performance measurements should be transformed into key performance indicators (KPIs) for evaluating road freight transport companies' performance (Elgazar et al., 2023; Hadavi et al., 2019). The subsequent section delves into presenting the research's objectives, aims, and research questions.

1.2. Research Aim, Objectives, and Questions

1.2.1. Research Aim

The research aims to develop a performance measurement framework for road freight transport companies, enabling them to monitor their performance, integrate technological applications, and enhance their decision-making towards sustainability.

1.2.2. Research Objectives

There are four research objectives underpinning this research project:

a. To develop a theoretical road freight transport performance measurement framework extracted from the literature review.

A review will be carried out to identify the research gaps, research questions, and research variables. Following this, the theoretical road freight transport performance measurement framework will be developed.

In achieving this objective, the primary challenges encountered by the road freight transport sector from a sustainable viewpoint will be pinpointed. Furthermore, the key components and performance measurements, extracted from the literature review, to be integrated into the developed road freight

transport performance measurement framework will be documented. Additionally, an investigation into the role of adopting technologies embedded within each element of the developed road freight transport performance measurement framework will be conducted.

b. To develop a conceptual framework tailored to the business context.

By evaluating the present state of the Egyptian road freight transport industry and conducting semi-structured interviews, a conceptual road freight transport performance measurement framework tailored to the business context will be formulated.

c. To test and validate the developed road freight transport performance measurement framework through conducting an empirical study in Egypt.

By carrying out surveys, the developed road freight transport performance measurement framework will be validated, and the research variables will be tested.

d. To propose a roadmap for adopting the applied road freight transport performance measurement framework within the Egyptian context, and to outline strategies that road freight transport companies could adopt to overcome these obstacles.

A roadmap is proposed to explore and pinpoint the key challenges in implementing the suggested framework in the Egyptian market. Solutions will be derived from participants to mitigate these potential challenges.

Each phase of the research aims to provide a comprehensive response, addressing the outlined research objectives, and consequently attaining the primary research goal (refer to Figure 1.1). The subsequent section will introduce the formulated research questions along with the intended objectives for each of them.

1.2.3. Research Questions

Ward & Kennedy (2017) stated that one of the creative tools that adds value to research studies is the formulation of research questions. This chapter introduces the formulated research questions and examines the approaches employed to attain clear responses for each of them.

Lane (2018) observed that answering research questions require specific criteria, including sufficient and relevant scientific data. They emphasised that defining research aims and objectives is essential to establish the necessary research framework and methods, and to establish connections between the answers and research hypotheses or to demonstrate associations among the research variables.

1. **What are the issues affecting the performance of road freight transport companies from a sustainable viewpoint?**

The purpose of this question is to critically assess previous studies conducted on road freight transport performance measurement. This review aims to identify the primary challenges encountered by this sector at an operational level. Notably, the industry commonly faces issues such as the inadequate integration of technologies in performance measurement (UNCTAD, 2017), traffic congestion, maintenance of infrastructure, non-enforcement of regulations and policies in certain countries, and a shortage of drivers in developed nations, along with a deficiency of qualified and well-trained drivers in developing ones. Subsequently, the question involves the incorporation of a range of performance measurements that can serve as Key Performance Indicators (KPIs) for various road freight transport companies. These KPIs are intended to gauge performance from a sustainable perspective. As a result, a performance measurement framework for road freight transport, centred on sustainability, is formulated to address the aforementioned challenges.

2. **To what extent can technology assist in mitigating the challenges encountered by the road freight transport sector and achieving sustainability?**

This question focuses on n examining the impact of technological applications and innovative solutions on enhancing overall performance. It has been observed that the road freight transport industry faces common challenges, including the lack of integration of technologies within each element during the creation of a performance measurement framework. In line with this observation, the envisaged road freight transport performance measurement framework, derived from the literature review, will be formulated.

3. **What key elements must be incorporated when developing a performance measurement framework for a road freight transport company?**

In this research, the proposed road freight transport performance measurement framework encompasses a set of performance measurements intended for assessing the performance of road freight transport companies upon the adoption of technology, thus exploring its influence on their overall operational effectiveness. By employing semi-structured interviews and implementing the Delphi method, participants' perspectives are gathered to discern road freight transport challenges and to evaluate the impact of adopting technological applications in enhancing sustainability within the Egyptian context. Subsequently, the envisaged road freight transport performance measurement framework is developed, tailored to the Egyptian context.

Following this, the developed road freight transport performance measurement system is validated through the execution of surveys. Therefore, semi-structured interviews and surveys are conducted within Egyptian road freight transport companies to collect participants' viewpoints concerning the establishment of a performance measurement framework within the Egyptian context. The aim is to identify the array of performance measurements to be included within it.

4. **What potential obstacles might road freight transport companies encounter while implementing the developed road freight transport performance measurement framework?**

This question is addressed through the execution of focus groups within various Egyptian road freight transport companies, showcasing the practicality of the developed road freight transport performance measurement framework. The discussions encompass obstacles, barriers, and challenges that road freight transport companies could encounter when implementing this system.

5. **What strategies could road freight transport companies employ to overcome these obstacles?**

This question is addressed through the facilitation of focus groups involving participants from the road freight transport industry. By recognizing the obstacles, the research endeavours to formulate a road freight transport performance measurement framework capable of surmounting the complete spectrum of potential barriers encountered by the road freight transport sector. Figure 1.1 below illustrates the interconnection among the research objectives, questions, and overarching aim.

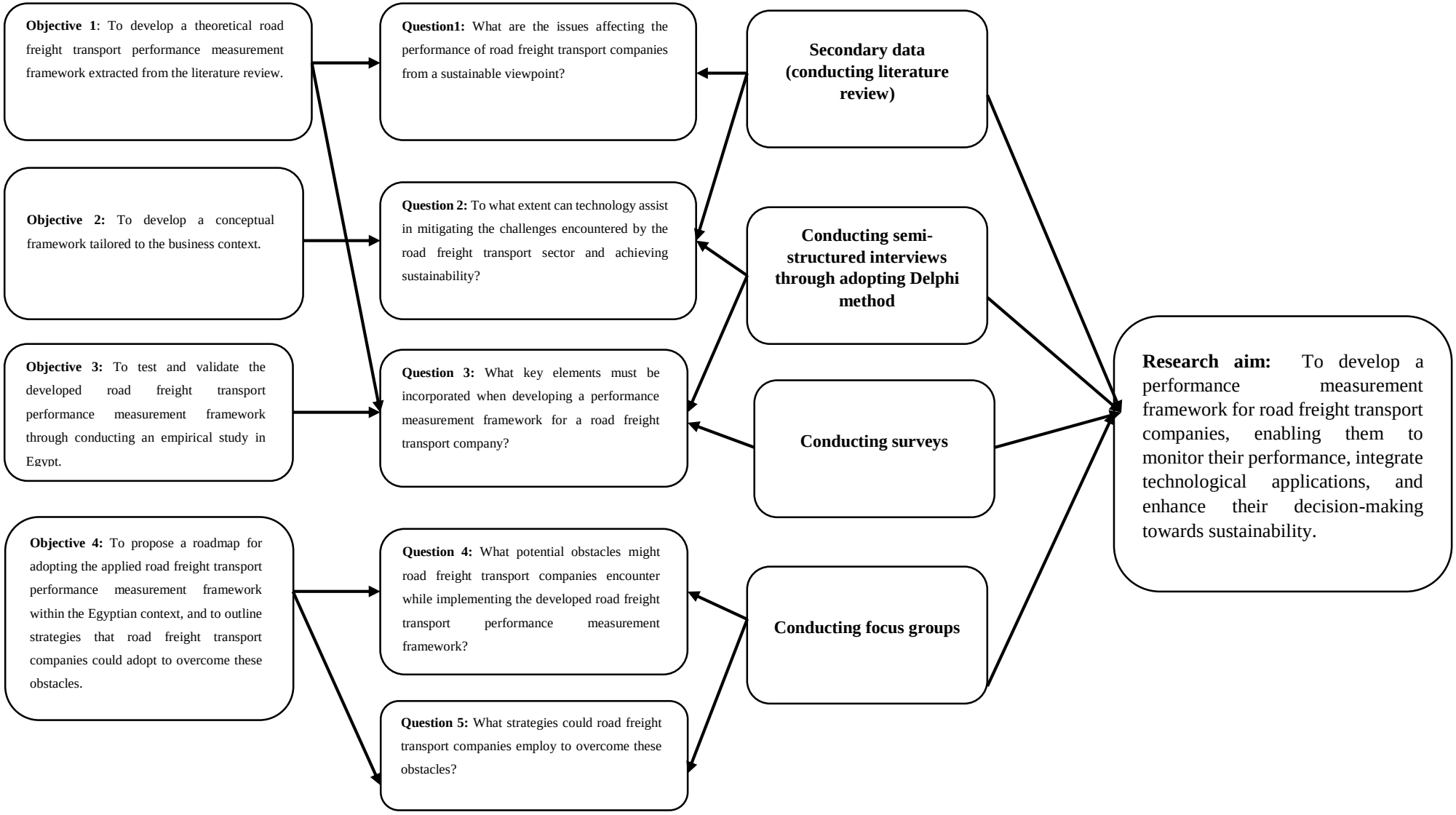


Figure 1.1 The Relationship between the Research Objectives, Questions, and Aim

1.3. Research Methodology

This research adopts the positivism philosophy and employs a deductive approach, employing an explanatory mixed methods approach that combines both quantitative and qualitative methods (Trochim et al., 2001; Azorin, 2016). To accomplish the research objectives, the research methodology is divided into four phases, as outlined below:

1. Analysing previous studies conducted in the domains of sustainability, performance measurement, and road freight transport has aided in identifying the necessary research gaps. This, in turn, has facilitated the formulation of research questions and objectives to attain the primary research aim. Furthermore, an extensive literature review was conducted concerning road freight transport performance measurement, with the aim of proposing a comprehensive road freight transport performance measurement framework.

2. Using the Delphi method would empower the researcher to gather participants' viewpoints concerning the developed road freight transport performance measurement system, achieved through iterative rounds until a consensus is reached (Zohrabi, 2013).

3. Employing surveys validates the developed performance measurement framework by examining the relationships between various research variables (Melander et al., 2019)

4. Conducting focus groups with individuals from Egyptian road freight transport companies will aid in formulating a roadmap for the implementation of the developed road freight transport performance measurement framework.

1.4. Research Originality

Most economies heavily rely on road transport to facilitate the movement of freight from origin to final destination (Noguerol et al., 2018). This dependence has experienced a recent sharp rise, leading to an escalation in challenges that adversely affect the sector (Engström, 2016). These challenges impede the performance of road freight transport companies and hinder the achievement of sustainability objectives. Although existing performance measurement systems gauge company performance, some approach sustainable freight transport matters from a strategic perspective, focusing on sector-wide planning rather than enhancing day-to-day operations (Elgazar et al., 2023; UNCTAD, 2017). To date, limited research has tackled the operational-level performance measurement of freight transport companies, especially in the context of road transport. An operational-level framework capable of quantifying actions from the economic, environmental, and social sustainability perspectives remains absent (Tian et al., 2020). While several studies have examined technology's role in improving performance, few have explored the impact of embedding technologies in each element of the performance measurement framework (Villamizar et al., 2020; Zgonc et al., 2019; Schulte et al., 2018).

This research introduces originality by integrating diverse dimensions with sustainable aspects. Through the development of a road freight transport performance measurement framework, sustainability considerations are incorporated into each captured element by embedding technologies. This approach empowers road freight transport managers to discern aspects and dimensions requiring technological enhancements. Furthermore, this framework enables operational-level performance measurement for road freight transport companies and holds potential for application in various countries and contexts by following the outlined roadmap.

Additionally, this research offers an opportunity to test relationships among variables within the developed road freight transport performance measurement framework, shedding light on their impacts on sustainability. Employing varied methodological tools provides a comprehensive view of the primary challenges faced by the sector and the role of technologies and performance measurement from a sustainable standpoint.

Furthermore, the empirical study conducted within this research yields a proposed roadmap for implementing the developed road freight performance measurement framework and ensures comprehensive testing and evaluation of all variables. Egypt has been selected as the study's focus due to its status as a developing nation that currently lacks an implemented performance measurement system in this sector. Given the sector's crucial role in the nation's economy, significant attention is warranted to enhance its performance. The subsequent section outlines the structure of the thesis.

1.5. Structure of Thesis

This dissertation is divided into seven chapters as follows:

Chapter One: Introduction

This chapter aims to introduce the research topic, present the research questions, outline the research aims and overarching objectives. It provides an overview of the research methodology, details the research's originality, and concludes by outlining the thesis structure.

Chapter Two: Literature Review

This chapter reviews and critically analyses previous studies conducted in the field of road freight transport, emphasising its importance, performance measurement, sustainability, and road freight transport performance measurement.

Chapter Three: Research Methodology

In this chapter, the research methods, philosophies, approaches and research proposition, data collection tools and methods of analysis are presented.

Chapter Four: Analysing the Road Freight Transport Sector in Egypt： Delphi Analysis

This chapter provides an overview of the global road transport industry, with a specific focus on Egypt, where the empirical study for this research is conducted, highlighted, and analysed. Furthermore, it presents the results and discussions arising from the analysis of the semi-structured interviews.

Chapter Five: Empirical Study on the Egyptian Road Freight Transport Companies

In this chapter, the results and discussions of the survey analysis are presented. Additionally, the findings from the focus groups conducted with Egyptian road freight transport companies are examined to validate the developed road freight transport performance measurement framework. Furthermore, a proposed roadmap for the application of the framework is provided.

Chapter Six: Discussion

In this chapter, the findings from each research phase are highlighted and interpreted. The results of the empirical study are discussed in conjunction with the developed road freight transport performance measurement framework within the Egyptian context.

Chapter Seven: Conclusion and Recommendations

A conclusion is drawn from the research, and recommendations for further work are proposed. Table 1.1 illustrates the main objective of each chapter in relation to the thesis structure.

Table 1.1 Chapter's Content in relation to Thesis Structure

Chapter's Number	Chapter's objective
1	• To identify research importance, research aim, and research objectives. • To formulate research questions. • To ascertain research originality.
2	• To identify the challenges facing the road freight transport sector. • To recognise the role of technology adoption in enhancing the road freight transport sector, with specific consideration of sustainability goals. • To identify research gaps. • To develop a road performance measurement framework incorporating three sustainable aspects (economic, social, environmental), along with potential technologies and a set of performance measurements.
3	• To identify the most appropriate research methods, research design, tools, and sampling size to be employed in this research
4	• To analyse the present condition of the road freight transport sector in Egypt. • To categorise themes, sub-themes, and codes derived from the semi-structured interviews. • To present the consensus of participants on problems identified in the literature review (Delphi method), encompassing a comprehensive view of sector challenges, the impact of technology adoption, and sustainable performance measurement. • To develop a road freight transport performance measurement framework tailored to the Egyptian context.
5	• To examine the relationships between the various variables incorporated in the developed road freight transport performance measurement framework and their effects on sustainability, based on participants' survey responses. • To formulate a roadmap for the implementation of the developed road freight transport performance measurement framework in the Egyptian context, utilizing focus groups.
6	• To compare, interpret, and discuss the research findings from each research phase. • To present the results of the empirical study. • To delve into the discussion of the road freight transport performance measurement framework within the Egyptian context.
7	• To conclude by achieving the realisation of each research objective, addressing research questions, and fulfilling the main research objectives. • To identify the research limitations encountered in each research phase. • To provide additional recommendations for researchers to explore this field further.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

This chapter provides an extensive review of the road transport sector by emphasising its significance, exploring sustainability aspects within the road freight transport sector, and investigating performance measurement systems.

A comprehensive examination of previous studies conducted on road freight transport performance measurement systems (PMS) is presented in this chapter. This review aims to capture essential performance indicators considering the three dimensions of sustainability. Moreover, the chapter delves into the role of adopting technological applications in addressing road freight transport challenges. This investigation serves to thoroughly analyse and underscore the correlation between technology adoption and the enhancement of performance for road freight transport companies.

Furthermore, a summary of the tools employed for measuring these crucial key performance indicators (KPIs) is provided. This presentation enhances understanding regarding the impact of evaluating road freight companies' performance not only on an operational level but also from a sustainability perspective.

2.2. The Economic Role of Road Freight Transport

Recently, supply chain activities, particularly transportation and logistics functions, have experienced disruptions due to unforeseen crises such as the COVID-19 pandemic (Switata et al., 2021) and global political issues including conflicts like the China-USA war and Ukraine situation, which have exerted added pressure on the road transport sector in terms of sustainability (Washington, 2022). This sector has been significantly affected, given that road transport serves as a primary alternative in times of crisis (Lacka et al., 2021).

Road freight transport constitutes a vital economic activity, recognised as indispensable for the proper functioning of economies worldwide (Elgazar et al., 2023; ERTRAC, 2019). The movement of goods from one location to another necessitates physical transportation. Over the past two decades, international trade in Europe has demonstrated dynamic growth, underscoring the increasing economic role of road transport in facilitating the movement of goods (Kunaka, et al., 2013). This mode of transport has become essential for countries, enabling the transportation of finished goods, raw materials, and production tools across various zones and regions (Pison, 2018).

Presently, road haulage is a pivotal component in transporting diverse loads, including break, dry and bulk cargoes, in addition to containers (Carlan, et al., 2019). Consequently, road freight transport plays a central role in freight transportation within Europe, serving to connect most existing European ports (El-Baz, 2011). The reliance on road-based freight transport has increased due to its contribution to the economy through the movement of large quantities of raw materials, semi-finished and finished goods within the supply chain networks to meet consumer demands (Piecyk & McKinnon, 2010). Despite its significant economic impact, it also carries adverse environmental and social consequences (Merchan et al., 2019). Given its essential role in European economic development, road freight transport companies should prioritize enhancing competitiveness by embracing various aspects such as technology adoption, service quality, management, and safety standards (Besselink et al., 2016).

The critical nature of transportation, particularly within the road transport sector, was underscored during events like the Russia-Ukraine war, leading to increased diesel costs that influenced transportation expenses (Financieras, 2022; Washington, 2022). Similarly, the COVID-19 pandemic had a significant and direct impact on the transportation sector, particularly on road transport, as air and sea transport halted, intensifying reliance on road-based transportation (Elgazar et al., 2023).

Given the importance of road freight transport, various initiatives and conventions have been established to enhance sector performance. The International Road Union (IRU), established in 1948 to facilitate trade and cooperation across European countries, is a global industry association dedicated to addressing sector challenges and promoting sustainability for both freight and passenger transport (Carlan et al., 2019). In collaboration with the World Bank, the IRU has introduced a guide for Road Freight Transport Services Reform, emphasising the role of efficient trucking in simplifying trade, reducing poverty, and fostering prosperity. This partnership has focused on key areas such as driver significance, vehicle conditions, technical inspections, and business regulations, successfully enhancing quality and competition across nations. The IRU's efforts primarily target governments and policymakers in developing and emerging economies, recognizing the critical role of road transport in their cargo mobility. It has recommended a comprehensive framework for the functioning of existing systems (World Bank & IRU, 2017).

In response to recent crises like the COVID-19 pandemic, the IRU has launched IRU Intelligence to alleviate negative impacts on truck drivers, considering the growing reliance on road transport (Lacka et al., 2021). Collectively, these endeavours contribute to the continuous improvement of the road freight transport sector (Elgazar et al., 2023; World Bank & IRU, 2017).

The IRU has made a significant contribution through the establishment of the IRU Academy, recognised as the world's foremost global professional road transport training organisation. Operating through a network of 65 Associate Training Institutes in over 46 countries, the Academy annually trains thousands

of drivers and transport operators. It also initiates campaigns to raise awareness about specific concerns and elevate global standards in professional road transport training, particularly focusing on road safety (Carlan et al., 2019).

Performance measurement endeavours encompass the creation of bilateral road transport agreements (BRTAs) with other nations. These agreements serve as integral tools for implementing transport and trade integration strategies. Given the heavy reliance on road transport for trade in many countries, BRTAs are crucial, as they establish new paradigms for foreign trade relations. Over 80 percent of trade traffic in most countries is facilitated by road freight transport, making it a cornerstone of increasing trade competitiveness. Developing countries' recent strides in infrastructure and trade acceleration should align with substantial enhancements in road transport services to drive cost reduction (Kunaka et al., 2013).

The global economy has witnessed heightened growth, improved living standards, and reduced poverty. However, emerging economic challenges like rising costs and environmental burdens, such as increased air and noise pollution, persist. Concurrently, social issues such as discriminatory practices affecting working conditions, wages, and youth employment persist (Litman, 2003). Consequently, the importance of sustainability, encompassing economic, environmental, and social aspects, has escalated as a means to address and eliminate these issues (Johansson & Djuric, 2018).

As emphasised by Poliak et al. (2019), transportation serves as the backbone of economic activities. Consequently, the significance of various transport modes has grown, accompanied by unique challenges. Notably, insufficient investment in infrastructure hampers sector-wide benefits like enhanced accessibility and reduced travel time. Thus, conventions and agreements are crucial to organize, plan, and define the responsibilities and rights of involved parties. The CMR Convention, for instance, regulates international road freight transport, setting limits of liability and insurance for carriers. Membership primarily comprises European Union nations, including France, Turkey, Spain, Cyprus, and Ireland (Elgazar et al., 2023; Carlan et al., 2019). Another convention, the Tier Convention, is dedicated to road freight transport sustainability, environmental mitigation, and technology adoption for advancement (Tier Classification for SDG Indicators, 2019).

Filipowicz (2019) highlights another union designed to regulate new investment projects, known as the "One Belt and Road Initiative," with a focus on smooth cargo transportation along the Silk Road between China, Europe, and Africa. This union, the Eurasian Economic Union, consists of five main countries working to connect European countries with Africa (Poliak et al., 2019).

Notably, the IRU is dedicated to enhancing, streamlining, and setting protocols and agreements to elevate professionalism in the road transport sector. Furthermore, the IRU offers training courses for road transport managers and drivers to bolster safety and security, mitigating potential problems and sustainability barriers in road freight transport (Filipowicz, 2019). These international conventions and unions aim to address carriage liabilities and foster global connectivity (Poliak et al., 2019).

It's pertinent to acknowledge that progress in the international road transport sector has been unsatisfactory, particularly for countries outside the EU, based on Eurostat statistics (El-Baz, 2011). Numerous problems affecting overall sector performance are recognized, and performance measurement must effectively address and alleviate these problems to enhance performance. Moreover, the EU's rapid evolution within the road freight sector emphasizes the need for policymakers, stakeholders, and vested parties to maintain up-to-date data on the sector's structure and key developments (Elgazar et al., 2023; Armstrong, 2013; Road Freight Transport Vademecum Report, 2010).

The road freight transport sector demands further attention to measure and enhance performance while addressing ongoing challenges (World Bank, 2012). High costs, reduced profitability, road safety concerns, environmental issues, bureaucracy, and corruption are the primary challenges. Addressing these issues can foster increased competition, transparency, safety, and sustainability (Kunaka et al., 2013).

The World Bank's Global Mobility Report identifies barriers to enhancing the road transport sector. Specific strategies, including institutional and regulatory changes, infrastructure initiatives (e.g., electric vehicle charging stations, enhanced safety systems), incentives (e.g., tax and pricing mechanisms), and communication efforts (e.g., advocacy campaigns), must be developed to overcome these challenges (World Bank, 2012).

Mommens et al. (2016) emphasise the negative effects of substantial freight movement by road, including gas emissions, accidents, and noise pollution that affect health and lead to congestion impacting the economy. Consequently, both public and private sectors must collaborate to recognise the impact of current road freight transport systems, mitigate negative consequences, and improve performance to drive sustainability (Elgazar et al., 2023; Carvajal et al., 2018).

Road freight transport companies need to establish a robust strategy to define their mission, vision, and objectives, along with a set of performance measurement indicators applicable to their operations (Elgazar et al., 2023; Konsta & Plomaritou, 2012). Implementing a road freight transport performance measurement system that incorporates diverse dimensions and key performance indicators (KPIs) such as network and infrastructure, safety, travel time, congestion, energy consumption, and travel cost, can effectively gauge company performance and pinpoint areas for enhancement and effective competition (Varma, 2008).

While there is a growing recognition of the importance of sustainability across sectors like manufacturing, logistics, and transportation, especially road transport, existing performance measurement systems lack comprehensive KPIs like trip cost, accessibility, trip delay, and fuel consumption for road freight transport. Incorporating all sustainable dimensions is essential for assisting participants and managers in measuring their company's performance and identifying areas for improvement (Campos et al., 2018).

Technological adoption also emerges as a crucial theme. Technologies such as tracing and tracking systems, lighter vehicles, GPS, and alternate energy sources assist in measuring road freight transport performance through sustainable dimensions. These technologies monitor driver performance, address congestion issues, optimize routes to avoid maintenance needs, and offer alternative pathways (Li and Yu, 2017).

Dynamic market conditions and regulatory changes necessitate the adoption of new technological applications and shifts in performance and operations in the road freight transport market (Tubis & Wojciechowska, 2017). Companies seek innovative solutions to mitigate economic and environmental negative impacts while enhancing their competitive edge and achieving sustainability (Carlan, et al., 2019).

As the volume of freight transported by road is expected to increase in the future, especially in developing countries, road transport requires attention and improvement. It offers benefits such as cost-effectiveness, high road network density, reasonable transport time, flexibility in routes, door-to-door service, adaptability to customer needs, and minimal risk of goods damage during transportation (Lin-Xue et al., 2015). These attributes contribute to road transport's high reliance compared to other inland transport modes (Besselink et al., 2016).

Despite the increasing reliance on road freight transport, the sector faces challenges beyond sustainability aspects, spanning social, environmental, and economic dimensions (Burkovskis, 2008). To address these challenges, road freight transport companies are embracing technological solutions (Elgazar et al., 2023).

Environmental pollution, traffic congestion, and accidents contribute to negative environmental and economic impacts (Santen, 2013). Governments are advocating for sustainable road freight transport by promoting fuel efficiency, cleaner vehicles, and controlling truck growth by optimizing maximum truck weight (Burkovskis, 2008). The assessment of delivery process reliability, often measured in terms of time consumed, can offer insights into logistics operations control and address disturbances in road freight operations (Elgazar et al., 2023; Martin et al., 2016; Santen, 2013; Liimatainen et al., 2013).

Recognising the role of road freight transport in a country's economic development, efforts are being made to balance economic prosperity with environmental considerations (Burkovskis, 2008). While road freight

transport contributes significantly to economic and social well-being, it also generates negative environmental impacts. To mitigate climate change, reducing greenhouse gas emissions, particularly in road freight transport, is crucial (McKinnon et al., 2009).

Excessive regulations prevalent in many countries hinder the freight transport industry, leading to inefficiencies. These regulations often lack relevance to other transport terminals, resulting in complexities. These obstacles contribute to lower-quality freight service providers and a dearth of high-quality freight companies in certain regions (Elgazar et al., 2023; Zhang et al., 2012).

Noguerol et al. (2018), as well as Russo & Comi (2016), also highlighted sustainability issues related to freight transported by road, such as congestion, air, and noise pollution (environmental), high logistics costs, and consequently, elevated product prices (economic) (McKinnon et al., 2010). Up to this point, it has been observed that the road freight transport sector faces significant challenges, including congestion, infrastructure maintenance, safety, and a scarcity of qualified drivers (Elgazar et al., 2023; Russo & Comi, 2016).

Challenges within the road transport industry can be categorized as environmental, social, and economic problems (see Table 2.1). Despite the vital role that technological solutions play in enhancing road freight sector performance, research indicates that many countries lack such solutions. Additionally, it is noted that there is no adequate performance measurement system for the road freight transport sector to quantify performance and identify areas in need of improvement (Zhang et al., 2012).

Many of the challenges highlighted in the road transport sector stem from the fact that trucks and vehicles are often owned by individual drivers rather than overarching companies. Smaller companies provide basic services such as paying management fees, conducting annual vehicle check-ups, and arranging insurance. Furthermore, a lack of a robust information network for vehicles and goods exists (ERTRAC, 2019). Due to the absence of unified service standards, freight transport companies manage vehicles as best they can within their budget, often failing to ensure transportation safety and goods security. This leads to poor performance and a compromised reputation. Moreover, being a low-profit industry, limited competition discourages the provision of standout services and the maintenance of high environmental standards (Armstrong, 2013; Road Freight Transport Statistics, 2019).

While road freight transport is vital to a country's economy, it introduces significant problems such as accidents, congestion, subpar infrastructure, pollution, and safety issues. Addressing these concerns would contribute to sustainability and improved performance (Holguín-Veras et al., 2016). The growing reliance on road freight transport has resulted in various negative effects, including congestion, pollution, and accidents (Atz et al., 2019; Zgonc et al., 2019).

To that end, transportation policymakers should consider various factors that contribute to sector improvement, such as focusing on road infrastructure maintenance and reducing traffic through the construction of new bridges and roads (Engstrom, 2016). It has also been noted that road freight transport can be enhanced in terms of performance management and measurement by identifying elements such as organizational objectives, technology adoption, setting rules and regulations, and fostering cooperation between public and private sectors and the government. Given the absence of an existing unified and comprehensive system encompassing various aspects of the road transport system, practitioners, academics, governments, and decision-makers are increasingly focused on addressing these issues (Tubis & Wojciechowska, 2017).

Another factor that merits consideration by different stakeholders and decision-makers in this industry is the increase in acts of terrorism, which has drawn attention to the need for risk management within road freight transport operations (Engstrom, 2016). Carrara et al. (2017) suggested that while freight transport is a main driver of economic development, it also contributes to negative impacts such as gas emissions. Therefore, there is a need for wider adoption of technological solutions in the road freight transport sector to mitigate negative effects, enhance performance, and ensure sustainable development. Given the increasing importance of road freight transport, companies could contribute to sustainability by integrating various disciplines to optimize costs, align demand with supply, and enhance the value chain through technology and sustainable practices (Schulte et al., 2018). While road freight transport efficiently facilitates the movement of goods, the resultant negative consequences undermine sustainable achievements. Thus, innovative solutions, including infrastructure improvement and enhanced tracking of truck movement, are strongly recommended to enhance the sector (Havenga & Simpson, 2018).

Carlan et al. (2019) assert that road freight transport is a substantial sector for employment, both directly and indirectly. Direct employment encompasses various road freight transport companies, varying in size and activities provided, as well as truck drivers and operation managers. Indirect employment involves numerous transport-related activities, including infrastructure building and maintenance, specific areas dedicated to road transport services (fuel stations, secured parking, cold chain storage, warehouses, and repair/maintenance activities), rescue and emergency services, forwarding and brokerage, vehicle manufacturing, and specialized insurance businesses. Adequate infrastructure guarantees physical movement between regions and countries. Nonetheless, road transport service providers should play an effective role in connecting societies and businesses, promoting economic investment shares between countries (The World Bank & IRU, 2017).

Road freight transport companies are willing to adopt sustainable practices to mitigate negative impacts, such as minimizing pollution and enhancing safety, both of which affect public health (Wolff et al., 2018). However, there remains a lack of an adequate performance measurement system that encompasses various

aspects of sustainability and assists companies in achieving cost-effectiveness. Consequently, a performance measurement system for the road freight transport industry should be developed, encompassing these diverse aspects, and establishing efficient sector regulations.

The road freight transport industry is projected to continue its global growth in the future, thereby potentially increasing negative impacts (Wolff et al., 2018). Therefore, it is highly recommended to seek innovative technological solutions to mitigate these impacts, enhance the sector's sustainability, and facilitate information exchange and communication towards sustainable practices (Macharis et al., 2019).

Sternad et al. (2019) and Zhang, Fan & Zhu (2012) emphasize that road freight transport is pivotal not only for road freight transport companies but also for countries' economies. Consequently, effective cost management is crucial for road freight transport companies. In alignment with this, companies categorize their cost structures into fixed costs (fuel, labour, toll costs) and variable costs (drivers and distance travelled). Hence, governments should play a guiding and supportive role in improving road freight transport by fostering an honest, competitive environment that safeguards social public interests and enhances road freight transportation efficiency (Campos, Simon, and Martins, 2019).

Villamizar et al. (2020) observe that an existing road freight transport performance measurement system operates in most countries. However, these systems lack the ability to quantify different sustainable aspects, particularly environmental ones (Sternad et al., 2019). Moreover, population growth and economic expansion have led to congestion problems, especially in transporting cargo from one point to another. Furthermore, various negative issues like accidents, land and infrastructure challenges, and pollution (noise and air) should be quantified and categorized under the three sustainability aspects (Campos, Simon, and Martins, 2019).

In summary, the road freight transport sector plays a crucial role in most countries' economies. The increasing reliance on road transport for cargo transportation offers advantages like door-to-door services, affordability, reasonable quantities, and manageable timeframes (Sternad et al., 2019; Zhang et al., 2012). However, this heavy dependency on the road freight transport sector results in various negative consequences with direct economic, environmental, and social effects. Effective management, adoption of purposeful technologies, and performance measurement are essential to mitigate these negative externalities and advance sustainability. However, there is a shortage of rules and regulations governing this sector. Limited innovation and technological tools are employed, and a comprehensive, quantified system for managing and measuring the performance of road freight transport operations is lacking (Elgazar et al., 2023; Macharis et al., 2019).

To accurately evaluate this sector's performance from legal, regulatory, and operational perspectives (Kunaka et al., 2013), universally agreed-upon guidelines should be developed, considering the creation of a sector-specific performance measurement system for road freight transport (Carlan et al., 2019).

As highlighted in previous sections, the global significance of the road freight transport sector is widely acknowledged, serving as a major resource for countries' economies. Road transport remains a dependable mode for the movement of goods within countries, both locally and internationally (Carlan et al., 2019).

2.3. Sustainability in Road Freight Transport Sector

The significance of practicing sustainability, encompassing its three facets – economic, environmental, and social – has been rapidly gaining prominence worldwide, primarily owing to its pivotal role in enhancing corporate and industry-wide performance. Moreover, sustainability is integral to safeguarding the environment and its surroundings. As a result, both public and private enterprises are increasingly recognizing its value and striving to integrate it into their operations (Rossi et al., 2016). Companies are acutely aware of the substantial benefits and are determined to surmount the challenges that arise from embedding sustainability practices within their operations. They are actively seeking more efficient and sustainable approaches to curtail operational expenses and reduce their ecological footprint. Despite the global recognition of the mounting importance of road freight transport, this sector contends with various issues that impede its effectiveness (Irigoyen et al., 2018).

It has been duly observed that freight transport stands as the primary source of gas emissions. Consequently, it is of paramount importance to seek viable solutions for mitigating these emissions within the supply chain system (James, 2013). The aspect of environmental sustainability addresses the repercussions of diverse processes on the environment and public health. Hence, sustainability is characterized as a triple bottom-line pursuit, aiming to achieve social and environmental progress alongside economic advancement (Litman et al., 2006; Martins et al., 2019). This underscores the principal assessment of sustainability, which involves a set of quantifiable indicators to track activities, assess them, and pinpoint challenges and shared performance objectives (Johansson et al., 2018).

While strides have been made toward sustainability within the modern economy and the trajectory of sustainable development is rapidly advancing globally, challenges persist across economic, environmental, and social dimensions (Xing et al., 2013). These dimensions present notable hurdles for transport companies and the broader industry, particularly for large corporations driven by profit motives (Sachs, 2012; Kad, 2015).

In the context of Africa and Asia, urbanization rates are witnessing a significant surge, with an estimated 2.5 billion new residential facilities projected to be constructed by 2050. This exponential growth not only impacts the economies of these countries but also exacerbates other issues. Notably, the incidence of road

accidents involving both drivers and pedestrians is on the rise in developing nations, currently accounting for nine out of ten fatalities. Furthermore, the transport sector contributes to 23 percent of energy-related greenhouse gas emissions in the environment, a figure poised to escalate to 33 percent by 2050 (Irigoyen et al., 2018).

The global toll of deaths attributed to air pollution has surged by 20 percent since 1990, now reaching approximately 4.2 million annually. Consequently, the adoption of technology holds promise in addressing these challenges, fostering the development of greener, safer, more comprehensive, and efficient transport systems. For instance, autonomous vehicles present the potential for heightened efficiency and fewer vehicles on the road, thereby contributing to reduced accident rates and alleviating stress levels among truck drivers, car drivers, and pedestrians. Smartphones and dedicated apps equipped with automated alert systems can streamline incident reporting and enhance the overall travel experience for drivers (Stojanović, 2017). However, it is essential to acknowledge that technology alone may not suffice, as evidenced by the potential for self-driving cars to exacerbate congestion and pollution without meticulous planning. Consequently, a cohesive strategy is imperative to manage the road freight transport sector, effectively controlling demand and nurturing sustainable mobility (Carvajal & Ayush, 2018). In this vein, researchers, and governments, both in developed and developing nations, are eagerly anticipating the adoption of diverse strategies, technologies, and innovative solutions to mitigate environmental impacts (Stojanović, 2017).

2.4. The International Transportation Sector: A Review of Different Countries' Approaches to Sustainability

The implementation of Huckepacks' transport technology in various European countries, as well as Canada, South America, and Australia, primarily focuses on the efficient delivery and pickup of swap bodies, containers, and full trucks using horizontal and vertical loading and unloading methods (Carvajal & Ayush, 2018). As a result, this technology contributes to reducing congestion and travel time, while facilitating the transportation of a substantial volume of cargo (Habus et al., 2019).

Hassan (2018) examined the adoption of newly developed technologies in certain African countries. For instance, despite being considered an underdeveloped nation, Ethiopia has demonstrated commendable performance in maintaining road infrastructure. The country places a strong emphasis on establishing rules and regulations for effective road transport management. Moreover, the Road Transport Authority (RTA) in Ethiopia has played a pivotal role in shaping the legislative framework, introducing measures to address challenges within the road transport sector (Habus et al., 2019).

In the case of Pakistan, the country benefits from a strategically advantageous geographical location with road connections to neighbouring nations. While Pakistan possesses adequate road infrastructure, the safety aspect remains a concern due to a high incidence of road accidents. In response, the road transport authority in Pakistan has formulated a strategy to enhance safety by upgrading and expanding road infrastructure and implementing monitoring systems for tracking and tracing (Nazir et al., 2016).

China has made significant strides in the road transport sector through the construction of new roads and highways, alongside the adoption of various technological applications. Notably, China is actively involved in major projects like the one-belt road, aimed at linking different countries along the Silk Road route (China Freight Transport and Shipping Report, 2020). Within Europe, Croatia serves as a prime example of a nation that has recently witnessed considerable development in its road transport infrastructure. The government's substantial investment in road and highway expansion has played a pivotal role in this progress. Nonetheless, substantial international investments are still required (Croatia Freight Transport and Shipping Report, 2020).

Bedinger et al. (2016), as well as Puodziukas, Svarpliene & Braga (2016), have highlighted the significant economic impact of road freight transport on countries. However, achieving sustainability is challenged by adverse consequences. Although technological applications offer advantages, their adoption and implementation within road freight transport companies remain limited (Elgazar et al., 2023; Tob-ogu, Kumar, and Cullen, 2018). Additionally, drivers often exhibit reluctance toward embracing new technologies (Lindh & Rudeke, 2018). This underscores the importance of governmental and private sector efforts to promote the adoption of technological solutions in the road freight transport sector, thereby mitigating challenges that hinder sustainability. Despite the continuous growth in the transportation industry, it continues to exert negative effects on both the environment and the economy (Elgazar et al., 2023; Lindh & Rudeke, 2018; Bedinger et al., 2016).

It is evident that the adoption and implementation rates of technological and innovative solutions remain low, thereby limiting improvements in the performance of the road freight transport sector. Many of these solutions are cost-intensive, making them inaccessible to all road freight transport companies (Elgazar et al., 2023). Another perspective from research highlights the lack of established performance measurement systems and the need for quantifying processes to identify sector-specific issues and enhance overall performance (Tob-ogu et al., 2018). Implementing a predefined performance measurement system at an operational level offers advantages in quantifying actions, pinpointing challenges, and elevating the sector's performance (Lindh & Rudeke, 2018; Bedinger et al., 2016).

2.5. Road Freight Transport Performance Measurement

A performance measurement revolution began five decades ago when companies started managing and controlling their budgets. However, it experienced a surge in the early 1990s when Neely observed that companies should consider different measurements rather than simply adopting innovative solutions (Nogning et al., 2017).

Neely et al. (2005) and Gunasekaran & Kobu (2007) illustrated that companies should be able to assess achievements, track processes, and identify problems to aid in decision-making. They emphasize the importance of measuring performance as it quantifies processes established to address issues and subsequently enhance overall performance (Wang et al., 2016).

Performance management has various definitions. It could be succinctly defined as "an activity that managers undertake to achieve predefined goals derived from the company's strategic objectives." Performance measurement is described as "the process of quantifying the effectiveness and efficiency of actions, where measurement is the quantification process and action leads to performance" (Lohman et al., 2004, pp. 267–269; Franceschini et al., 2019, p. 4).

Neely et al. (2005) posited that effectiveness signifies the extent to which customer requirements are met, while efficiency measures how company resources are utilized economically to achieve customer satisfaction. Moreover, performance measurement systems (PMS) are defined as quantifying various actions and processes to achieve both efficiency and effectiveness (Gunasekaran & Kobu, 2007). Thus, companies measure their performance to identify challenges, meet customers' needs, overcome issues, and base decisions and objectives on reality rather than assumptions (Zhang et al., 2012).

Measuring performance can assist in fostering a secure, innovative, and competitive market, playing a positive role in the development of various industries, including the road freight transport sector (Beamon, 1999; Neely, 2005; Zhang et al., 2012). Despite the importance of a performance measurement system, many existing systems lack integration of diverse measurements from sustainable perspectives that should be included as Key Performance Indicators (KPIs), thereby limiting their applicability. Furthermore, effective performance measurement management is not sufficiently implemented in most of these companies (Curtis et al., 2017; Franceschini et al., 2019).

Cottrell (2008) focused on performance measurement in freight transportation and noted that while performance measurements are widely implemented in the transportation sector, there is no consistent guidance for developing a performance measurement system in freight transport. Additionally, the measurements used in practice lack consistency. Consequently, establishing reliable performance metrics will assist the road freight industry in identifying critical issues that require evaluation (Landström & Palander, 2018).

Many of the existing performance measurement systems do not adequately encompass all aspects of performance measurement and metrics. For example, they may not account for varying levels of decision-making, different sustainable dimensions, and innovative measurements (Neely, 2005; Gunasekaran & Kobu, 2007). Furthermore, there is a deficiency in adapting performance measurement systems (PMS) to dynamic environments and revising strategies and plans over time (Shepherd & Günter, 2006; Gomes et al., 2011; Nogning et al., 2017; Carpejani et al., 2017).

Indeed, performance measurement and innovative solutions are essential factors for companies to outperform their competition, as they contribute to enhancing internal and external operations across various organizational levels (Neely, 1999; Neely, 2005; Carpejani et al., 2016). Therefore, integration is necessary between a company's strategic levels, the three pillars of sustainability, and the operational levels. While tailoring sustainable actions is contingent on the business type, performance measurement should be devised, managed, and implemented according to the company's objectives (Saunila, 2016; Sternad et al., 2019; Villamizar et al., 2020).

Nogning et al. (2017), Edgeman (2017), and Neely et al. (1995) have proposed that companies should not only assess social and environmental measurements from legal and ethical perspectives for internal operations or the broader sector, but also with a view toward global sustainability. For instance, in Canada, 40 percent of companies neglect to measure performance from an innovative standpoint, while only 8 percent of the total number of companies adopt innovative performance measurement. This underscores the need for further research on adopting innovative performance measurement. Over the past decade, literature on innovative performance measurement systems (PMS) has significantly expanded (Dubey et al., 2016; Watts & Connolly, 2012).

The importance of Key Performance Indicators (KPIs) has been acknowledged in numerous research studies, with KPIs serving the purpose of controlling, managing, and reporting a company's performance after quantifying various actions and processes. Both parties recognize the importance of establishing defined guidelines and criteria for selecting the most suitable KPIs. Achieving comprehensiveness and consistency across different organizational levels and sustainability aspects, all while considering the companies' objectives, is a challenge (Maestrini et al., 2018; Wiktorsson et al., 2018).

Performance measurement and indicators ensure that companies execute their objectives, processes, and operations effectively and efficiently, provided these companies strive to gain a competitive advantage over their rivals (Neely, 2005; Choong, 2013; Saunila, 2018). However, the dynamic business environment and variations in rules and regulations pose obstacles to their effective utilization. Moreover, uncertainties related to categorizing, quantifying, and implementing measurements and indicators present challenges to companies in adopting performance measurement systems (Franceschini et al., 2019; Ros

et al., 2019; Janic, 2020). The importance of adopting performance measurement systems in various industries, including the transport sector, has been increasingly recognized over the past decades (Neely, 2005).

Clearly, road freight transport assumes a pivotal role in international relations, connecting neighbouring countries and facilitating the movement of diverse cargoes (World Bank & IRU, 2017). Notably, in the realm of trade, road freight transport holds a predominant position. Consequently, a delicate balance must be struck between the government, responsible for setting rules and regulations for roads, railways, and waterways, and the private sector. However, nurturing this relationship is complicated by the globalization of manufacturing, which extends to more ports serving the logistics chain and increasing pressure on the sector. Thus, developing an efficient international performance measurement system for the road freight transport sector becomes a key challenge for nations aiming to compete in the global economy (Carvajal & Ayush, 2018).

In the Western Balkan countries, which encompass six nations including Albania, Bosnia and Herzegovina, Kosovo, FYR Macedonia, Montenegro, and Serbia, trucks are the primary mode of freight transport. However, the dominance of road transport in the freight sector gives rise to several concerns, such as unpredictable journey times, high logistics costs, congestion, and elevated levels of pollution and greenhouse gas emissions (Irigoyen et al., 2018).

The World Bank is striving to address these issues in the Western Balkans region. Despite this effort, the Global Competitiveness and Logistics Performance Indexes reveal significant potential for enhancing the quality of transport systems and custom-clearing processes in the area. This could be achieved through the establishment of qualification frameworks and the delivery of internationally standardized training. Encouraging eco-driving techniques, which reduce accidents, fines, fuel consumption, and vehicle maintenance, also holds promise. Clearly, guidelines and strategies are needed to foster a secure, reliable, and competitive road transport industry (World Bank & IRU, 2017).

In the 2012 World Bank report, Central America is depicted as facing increased road freight transport costs due to factors like high fuel prices, security expenses, empty container transfers, extended travel times, and insufficient investment in vehicle fleet maintenance and renewal. Moreover, travel times between points are influenced not only by unpredictable customs procedures, but also by other factors such as urban congestion, nocturnal travel restrictions for safety reasons, and inadequate road infrastructure. Vulnerability to natural disasters further limits accessibility, particularly for unpaved roads. To alleviate transportation expenses, comprehensive solutions must encompass synchronized customs systems, road infrastructure investment, and efforts to combat crime and violence (Carvajal & Ayush, 2018).

The road freight transport sector appears to grapple with similar challenges across diverse countries, regardless of their development status. While there's a collective emphasis on mitigating road freight transport issues through distinct strategies, road infrastructure development, and technology adoption for enhanced safety (Stojanović, 2017), companies still struggle to effectively adopt and utilize performance measurement systems. Moreover, a specialized performance measurement system designed specifically for evaluating the impact of innovative practices or a comprehensive road freight transport performance measurement system that encompasses the three pillars of sustainability is lacking (Choong, 2013). Despite the growing importance of Key Performance Indicators (KPIs) and the necessity of quantifying performance, their applicability remains limited across various sectors, including the road transport industry (Saunila, 2018) (refer to Table 2.1).

Table 2.1 A Summary of Research Findings and Limitations in Road Freight Transport Performance Measurement

Authors	Key Research Findings	Key Research Limitations
Lohman et al., 2004 Mckinnon, 2005 Harrison et al., 2006 Cotrell, 2008 Varma, 2008 Elvik et al., 2009 Brown et al., 2010 Mckinnon et al., 2010 Piecyk & Mckinnon, 2010 Elgazar et al., 2023	• The importance of measuring some sector's performances has been identified. • The problems facing the road freight transport sector have been highlighted and categorised from different sustainable aspects.	• There is a lack of adoption of technological practices and innovative solutions in this sector.
Zahurul Islam, 2013 Armstrong, 2013 Ducret, 2014 Jha et al., 2014 Visser et al., 2014 Engstrom, 2016 Mommens et al., 2016 Russo & Comi, 2016	• Opportunities for sustainable development through the incorporation of performance measurement and technology adoption have been discussed. • Existing performance measurement systems solely focus on the social aspect, the environmental aspect, the economic aspect, or at most two aspects.	• The existing performance measurement systems primarily focus on only one or two sustainable aspects.
Santen, 2017 Kovacs, 2017 Campos et al., 2019 ERTRAC, 2019 Road freight transport statistics, 2019 Anwar et al., 2020 Tian et al., 2020 Elgazar et al., 2023	• The challenges identified in road freight transport are expected to have various negative sustainable effects. • Adopting technologies should help mitigate the negative impacts.	• There is limited focus on the challenges within the road freight transport sector. • Existing road freight transport systems are designed primarily at the city level, while other systems are developed from a strategic perspective rather than an operational one.

The preceding discussion highlighted the significance of road freight transport for a country's economy, as well as the importance of measuring its performance. The discussion concluded with a summary of the primary research findings and the limitations of the road freight transport performance measurement system. It is evident from the discussion that a technological solution is genuinely needed to enhance organizational performance and promote sustainability within Egypt's road transport sector.

The subsequent section will conduct a comprehensive review of road freight transport performance measurement systems with the aim of formulating a framework that encompasses sustainable aspects, while also considering the adoption of technology.

2.6. Review of the Road Freight Transport Performance Measurement System

In this section, an extensive review of previous studies conducted in the field of road freight transport performance measurement systems and metrics will be undertaken to identify measures and Key Performance Indicators (KPIs) for the road freight transport sector, focusing on sustainable perspectives and the integration of technologies. This section will commence by outlining the methodology employed for conducting the review of existing literature, followed by a discussion of the findings.

2.6.1. Review Methodology

To analyse previous studies on road freight transport performance measurement systems, a narrative approach has been employed. This approach involves identifying key keywords, namely: sustainability in road freight transport, road freight transport performance measurement system, and road freight transport issues and technologies. The search was conducted between 2010 and 2022 across various databases, including Emerald, Scopus, Science Direct, Sustainability, and Web of Science.

Sixty papers were initially collected and subsequently refined to 40 papers through a filtering process. The selection of these papers was based on their relevance to the designated topic.

2.6.2. Review Discussion

The rapid expansion of road freight transportation in recent decades, driven by supply chain innovations like Just-In-Time (JIT), home deliveries, and e-shopping, coupled with population growth, has led to an upsurge in deliveries and the number of trucks in various regions (Browne et al., 2010; Visser et al., 2014). China's "One Belt-One Road" initiative aims to connect 68 countries through the Silk Road, enhancing their economies via international freight transport (Kellner et al., 2019). However, this growth in road freight transport has also brought about environmental issues (Anwar et al., 2020).

Researchers have extensively addressed the challenges facing the road freight transport sector from sustainable perspectives, encompassing environmental, social, and economic aspects (Alumur et al., 2018; Kellner et al., 2019; Anwar et al., 2020). Key problems identified by researchers in the road freight transport sector include congestion, road infrastructure maintenance and development, and driver training and qualifications (Hysing et al., 2015; Zain et al., 2016; Mbakwe et al., 2016; Alumur et al., 2018). The researchers have also emphasized that the three aspects of sustainability (economic, environmental, and social) are interconnected and should be addressed collectively (Engstrom, 2016).

Kellner et al. (2019) acknowledged the paramount importance of road freight transport in delivering goods, but the problems it engenders act as barriers to implementing just-in-time concepts. Issues like traffic congestion and cargo emissions directly impact both costs and the environment. Moreover, bottlenecks in road infrastructure linking different regions further influence the economy and the environment (Ducret, 2014).

Road freight transport has been recognized as a substantial source of income for many countries' economies. However, persistent issues persist in the sector. Social considerations, including drivers' professionalism, safety, working conditions, and wages, are vital factors. While each country efficiently manages its road freight transport sector at the national level, a lack of harmonization between countries at the international level stems from the absence of predefined rules and regulations. This inconsistency leads to negative repercussions for the road freight transport business,

underscoring the need for international standardization in managing and organizing this sector (Simurkov et al., 2018).

The movement of freight via road leads to various adverse impacts, such as accidents, overloaded trucks, gas emissions, and environmental harm, resulting in escalated costs for both road freight transport companies and nations. These impacts contribute to making road freight transport a prominent global political concern, and key issues in the sector encompass accidents, congestion, pollution, and climate change, which contribute to the external cost of the road freight transport sector (Elgazar et al., 2023; Salmon et al., 2016).

Although researchers tend to focus more on passenger travel than on freight travel, road freight has a more substantial and direct economic impact. The increasing number of freight trucks gives rise to sustainability challenges, including congestion, air pollution, noise, heightened trip and fuel costs, and elevated product prices. Road freight transport significantly contributes to congestion, impacting individuals, companies, and society economically. It also has environmental ramifications for current and future generations, and socially, it influences traffic accidents, working conditions, and gender equality. Additionally, road freight transport generates both external and internal costs, such as congestion, air and noise pollution, and accidents, affecting the competitiveness of the road freight transport sector (Gunasekaran et al., 2001).

The role of governments in aiding road freight companies for the advancement of countries should be acknowledged. However, challenges arise in comprehending and effectively practicing sustainability, as research studies lack specific definitions of sustainability and unified standards for its application (Moore et al., 2017; Hadavi et al., 2019). Sustainability remains a pivotal subject of study, with both researchers and practitioners recognizing the strong imperative to achieve it. Nevertheless, limited information exists concerning its application, particularly within the road freight transport sector (James, 2013). While governments steer companies towards sustainability in road freight transport, hurdles to attaining it persist. Previous studies have primarily focused on just one or two facets of sustainability, such as environmental or socioeconomic aspects (Goh & Yang, 2014).

The road freight transport sector grapples with diverse problems that carry direct negative environmental and social consequences. Overcoming these issues necessitates

collaboration among various stakeholders, including managers, road users, and policymakers. An ideally suited mechanism for addressing and measuring these concerns would be a pre-established performance measurement system (Chen et al., 2018).

Sustainable road freight transport has garnered significant attention from researchers, governments, and companies aiming to mitigate adverse impacts and augment overall industry performance (Li &Yu, 2017). While road transport remains the prevailing mode for freight movement due to superior performance, favourable transit time, and reasonable tariffs compared to alternative modes (Gunasekaran et al., 2001), the design of a performance measurement system that not only aids companies in realizing their objectives but also enhances their comprehensive performance remains a challenge (James, 2013).

Researchers have introduced performance measurement systems tailored to the road freight transport sector, applicable to strategic, tactical, or operational processes (Mbakwe et al., 2016; UNCTAD, 2017; Alumur et al., 2018; Villamizar et al., 2020). These systems can also find broader utility across various logistics realms, including transportation, warehousing, inventory control, order processing, and logistics administration (Mostert et al., 2016; Santén, 2017). Both researchers and practitioners are zealous about advancing sustainability goals to bolster the road freight transport sector and enhance performance (Ambrosino et al., 2019). Quantifying costs related to distance, delay, and congestion, while simultaneously addressing these issues, has the potential to elevate overall performance and reduce barriers to sustainability (Stenico et al., 2019).

For the enhancement of road transport companies' performance, a range of strategies have been suggested. These include augmenting freight volumes transported via road, advancing infrastructure and bridges, and establishing regulations for managing the freight transport sector both domestically and globally (Zhang, Fan & Zhu, 2012; Li and Yu, 2017). However, a unified quantification system for measuring operational performance of road freight transport companies and addressing sectoral issues is still absent (Behrends, 2017; UNCTAD, 2017; Villamizar et al., 2020). Additionally, the significance of technology adoption to mitigate problems and measure the performances of road freight transport companies has been underscored by various

researchers (Mittal et al., 2018; Elgazar, 2023). Innovative solutions are imperative to curtail negative impacts (Kellner et al., 2019).

Researchers have proposed that technologies can play a role in diminishing adverse environmental effects from road freight transport. Electric-powered and lightweight vehicles represent potential technological implementations. However, infrastructure improvements are requisite to accommodate these vehicles, including the provision of charging stations for electric vehicles powered by cleaner sources in road freight transport (Nicolaides et al., 2018; Miguel et al., 2019). Existing performance measurement systems utilizing technologies such as the Internet Routing Registry (IRR) system, empty running containers, and time service modelling frameworks have been suggested to alleviate congestion and evaluate infrastructure accessibility (Hysing et al., 2015; Zain et al., 2016; Mbakwe et al., 2016; Alumur et al., 2018).

Overall, the literature review reveals a compelling need for a pre-established performance measurement system in the road freight transport sector, encompassing the three sustainable dimensions and technology (Russo & Comi, 2016; UNCTAD, 2017; Schulte et al., 2018; Elgazar et al., 2023). This research makes a valuable contribution to knowledge by proposing a road freight transport performance measurement framework that spans various sustainability facets. Tailored specifically for road freight transport companies, this framework aims to gauge their operational performance through the integration of technological innovations. It also delineates a set of performance metrics to be incorporated as Key Performance Indicators (KPIs) alongside technological advancements, thereby aiding diverse road freight transport companies in assessing their performance and identifying areas that require enhancement from a technological standpoint. This, in turn, furthers the cause of sustainable development (see section 2.7).

Table 2.2 Research Limitations in Road Freight Transport Sector

Research Area	Authors/ Year	Research Limitations
Road freight transport problems from sustainable perspectives	Cottrel, 2008; Elvik et al., 2009; McKinnon et al., 2010; Hysing et al., 2015; Kirschstenin et al., 2015; Salmon et al., 2016; Zain et al., 2016; Mbakwe et al., 2016; Liang et al., 2016; Alumur et al., 2018; Oskarbski et al., 2018; Elgazar et al., 2023.	Various problems confront this sector from distinct sustainable perspectives. However, there remains a dearth of comprehension regarding the impacts of these problems on the diverse dimensions of sustainability. Moreover, the absence of enforced rules and regulations to govern this sector, along with the lack of predefined and harmonized regulations among countries to effectively monitor this sector, are noteworthy challenges.
Performance measurement in the road freight transport sector	Gunasekaran et al., 2001; Zhang et al., 2015; Engstrom, 2016; Liang et al., 2016; Russo & Comi, 2016; Mostert et al., 2016; Behrends, 2017; UNCTAD, 2017; Santén, 2017; Li and Yu, 2017; Simurkov et al., 2018; Oskarbski et al., 2018; Tawfik et al., 2018; Ambrosino et al., 2019; Stenico et al., 2019; Villamizar et al., 2020.	While there exist various performance measures for assessing the performance of this sector, there remains an insufficiency in quantifying the actions and metrics pertaining to road freight transport companies' performance. Furthermore, there is a deficiency in identifying a comprehensive set of performance measures from a sustainable perspective that can be translated into key performance indicators (KPIs) for evaluating the performance of diverse road freight transport companies, which may differ in size and operations.
Existing road freight transport	Cottrell, 2008; James, 2013; Goh & Yang, 2014; Zhang et al., 2015; Hysing et al., 2015; Zain et al.,	Various performance measurement systems can be employed to gauge the performance of the road freight transport sector. However, a dedicated performance

performance measurement systems	2016; Mbakwe et al., 2016; Li and Yu, 2017; UNCTAD, 2017; Moore et al., 2017; Shams et al., 2017; Chen et al., 2018; Alumur et al., 2018; Hadavi et al., 2019.	measurement system tailored specifically for road freight transport companies to assess their operational-level performance is currently absent. Furthermore, the current performance measurement systems predominantly address one or two sustainable dimensions, yet they fall short in comprehensively addressing all three sustainable aspects.
Utilising technologies and innovative practices in road freight transport sector	Browne et al., 2010; Kunaka, 2013; Visser et al., 2014; Ducret, 2016; Engstrom, 2016; Rodseth, 2017; Mittal et al., 2018; Schulte et al., 2018; Nicolaides et al., 2019; Miguel et al., 2019; Kellner et al., 2019; Elgazar et al., 2023.	While the adoption of technologies and innovative practices presents itself as a potential solution to elevate the performance of this sector and alleviate the anticipated road freight transport challenges, there remains a deficiency in their adoption.

2.6.3. Review Findings

This research endeavours to develop a road freight transport performance measurement system through the lens of sustainability, with technology as a central aspect, and the issues of congestion, infrastructure maintenance, and driver training and qualifications as key dimensions. The primary problems, as identified in previous studies, that exert adverse effects on the performance of road freight transport companies are categorized within the three sustainable domains: environmental, economic, and social. Specifically, the congestion problem and infrastructure maintenance fall under the purview of economic and environmental aspects, respectively. Various performance measurements are employed to gauge their impacts from both economic and environmental perspectives (Engstrom, 2016; Behrends, 2017). Meanwhile, the driver training and qualifications concern is positioned within the social aspect within the developed road freight transport performance measurement system. Diverse performance metrics are addressed to assist decision-makers within road freight transport companies in assessing the impact of these problems on company performance.

Furthermore, technological applications are designated as a key aspect integrated into the evolved road freight transport performance measurement system. This integration enables the measurement of the correlation between the adoption of technological apps and innovative solutions and the enhancement of road freight transport companies' performance by ameliorating the adverse effects of the identified problems (Goh & Yang, 2014).

2.6.3.1. Congestion Reduction

Newly developing countries, such as Egypt and India, are experiencing rapid growth, resulting in increased populations and a corresponding surge in truck movements for freight transportation. However, there has not been a commensurate expansion in transportation infrastructure development (Kok, Hans & Schutten, 2012), leading to the emergence of traffic congestion. The disparity between growing traffic and limited road network capacity gives rise to the daily phenomenon known as "traffic congestion." This congestion issue directly affects travel time, air, and noise pollution, heightened operating costs, and reduced productivity (Khanal, 2012).

Vannieuwenhuyse et al. (2003) observed that freight transportation has become a critical concern due to burgeoning congestion problems and heightened environmental and safety considerations. Furthermore, the principal negative externalities stemming from congestion encompass elevated transport expenses, diminished reliability and flexibility, extended travel times, compromised safety, and the constrained capacity of the road transport network. Additionally, vehicle breakdowns, traffic accidents, lane blockages, and severe weather incidents are the primary outcomes of congestion. Congestion profoundly

influences both the sustainable environmental and economic facets by contributing to increased travel costs, prolonged trip durations, and escalated pollution (Taylor, 2008).

Boussier et al. (2011) asserted that congestion arises from vehicles searching for parking spots to complete freight deliveries. This exacerbates trip delays and reduces overall quality and reliability. In certain instances, inefficient logistical systems exacerbate congestion by employing surplus and unnecessary vehicles and vans. Peak period congestion during rush hours in diverse areas amplifies trip expenses and exacerbates environmental impacts, including rapid CO2 emissions escalation (Figliozzi, 2011).

Traffic congestion significantly affects diverse businesses, chiefly by causing delays in customer orders and driving up truck driver hiring costs (Boussier et al., 2011). Traffic congestion results from a range of factors, including predictable ones such as heightened traffic during rush hours, and less predictable ones such as weather conditions and road accidents. Predictable factors account for 70-87% of all traffic congestion, which can be mitigated by judicious route planning and scheduling (Kok et al., 2012).

Congestion has been identified as a pivotal contributor to compromising truck driver safety by adversely impacting their working conditions. It also amplifies fuel consumption, leading to wastage of fuel, augmented trip costs, and diminished productivity. These issues stem from the mounting number of trucks and the constrained capacity of available transportation networks (Mckinnon et al., 2009; European Commission, 2011). Additionally, congestion directly affects travel times and indirectly influences fuel costs, air and noise pollution, and stress levels. Notably, technology is anticipated to play a substantial role in addressing and ameliorating these concerns (Mckinnon, 2015; Magazi et al., 2015; Demir et al., 2015).

The rapid expansion of population size and improvement in living standards have exerted immense pressure on road traffic, contributing to congestion. This not only disrupts truck movements but also escalates trip expenses, amplifies noise and air pollution, reduces road user safety, and hampers mobility. Traffic congestion compromises city attractiveness and undermines the overall effectiveness of the transportation system (Grote et al., 2016; Ru Li, 2016). This is due to increased travel times, fuel consumption, transportation costs, and a surge in accidents and pollution levels. Moreover, the growing movement of trucks aggravates congestion, resulting in heightened gas emissions that detrimentally affect air quality and public health. Developing countries are particularly susceptible to this issue, as their towns and cities are projected to contribute 80% of total gas emissions by 2030. Hence, these countries need to prioritize emissions reduction (Puodziukas et al., 2016; Tian et al., 2012).

It is evident that congestion presents a major challenge confronting the road freight transport sector, coinciding with the global population increase. Additionally, the mounting demand for diverse cargo necessitates a substantial number of trucks to facilitate transportation from production to consumption sites. Congestion poses a significant threat to the road transport sector, negatively impacting economies, and the environment (Magazi et al., 2015). Moreover, it adversely affects the performance of road freight transport companies by raising operating costs, fuel expenses, fuel consumption, travel duration, gas emissions, trip expenses, driver stress, and overall productivity (Elgazar et al., 2023). Another noteworthy aspect is that congestion arises due to limited infrastructure and a surge in the number of cars and trucks, particularly during rush hours (Demir et al., 2015) (see Table 2.3). Consequently, road infrastructure maintenance emerges as another significant challenge for the road freight transport sector (Bruijn, 2007). Table 2.2 outlines the primary performance measurements to aid in understanding the impact of congestion on road freight transport companies, along with various techniques to measure each from economic and environmental standpoints. The subsequent section delves into the importance of upholding road infrastructure to enhance the road freight transport sector.

Table 2.3 Performance Measurement Definitions and the Tools used for Measuring the Congestion Problem from Different Sustainable Aspects

Environmental Aspect	Congestion Problem		
	Performance Measurement	Definitions	Techniques
	Fuel and Energy Consumption	Re Hermann et al. (2018), Figliozzi (2011), and Frey et al. (2008) have indicated that the heightened demand for freight movement results in increased energy and fuel consumption. This escalation contributes to adverse environmental effects, particularly due to the unpredictable fluctuation in emissions and fuel consumption, which becomes pronounced when travel speed declines from above 30 mph to 12.5 mph or further down to 5 mph. Furthermore, frequent speed changes, such as those encountered in stop-and-go traffic conditions, further elevate emission rates due to fuel consumption. Hence, there is a compelling need for both environmental and economic incentives to mitigate the escalating negative impacts of rapidly increasing CO2 emissions.	Fuel consumption rate equals Travel speed times acceleration rates (Rehermann et al., 2018)
	Noise Problem	There are various types of noise, including construction noise (from machines) and external noise from road vehicles. Additionally, noise-related issues have significant implications for human health. Technology amplifies the effects of noise and has an environmental impact on the surrounding areas (Aygul et al., 2017; Boussier et al., 2011).	Noise measurement include frequency, length of exposure to noise, the average noise value, and levels (Aygul et al., 2017)
	Traffic Jams	Traffic congestion is caused by both predictable factors, such as the high volume of traffic during peak hours, and less predictable factors, such as weather conditions or road accidents. Meanwhile, delays caused by peak-hour traffic congestion are expected and contribute significantly (70–87%) to overall traffic congestion. Traffic gridlocks emerge due to the continuous growth in traffic and the limited capacity of road networks. As a result, traffic congestion has become an everyday occurrence (Kok et al., 2012).	Council-devised monitors include various congestion measurements, including Vehicle Miles and Hours of Travel, Average Travel Speed (mph), Person Miles of Travel (VMT), and Person Hours of Travel (Roe et al., 2012)
	Severe Weather	Severe weather, including bad weather, rain, temperature, humidity, and wind, directly impacts daily life and truck movement (Esquivel et al., 2019).	Weather Forecasting Applications. Weather Forecast $\frac{deltaA}{deltaT}$ (A) = where delta A is the change of the weather in a certain location, and Delta T is the duration in which the change in weather occurs (Esquivel et al., 2019)

	Car Exhaust Rate	The dependency on motor vehicles and trucks increases the gas emissions produced from car engines, which impacts the environment negatively and increases cost (Smit et al., 2019).	Measurement of car exhaust rate. The mass flow rate of an engine depends on the air density at the intake manifold (PA,o), the volumetric efficiency (r¡v), the engine displacement (Vd), the engine speed (n) and the air jfuel ratio (mFjmA), mE = t·l)v·Vd.n'QA,a{1+(mFjmA)] (González et al., 2016). Another tool: Several methods are used to measure vehicle emissions, such as on-board emission measurements (PEMS), remote sensing, near-road air quality measurements, and tunnel studies (Smit et al., 2019).
Economic Aspect	Congestion Problem		
	Performance Measurement	Definitions	Tools
	Reliability	Inability to reach the final destination on planned time (Chen et al., 2016)	Reliability equals Actual time - Nominal Time (Chen et al., 2016).
	Mobility	Capability of freight and passengers to move smoothly, cheaply and with a steady speed (Lomax et al., 2002)	Mobility = q*k*u, where q is flow in veh/h, k is density in veh/km, and u is speed in km/h (Lomax et al., 2002).
	Traffic Accidents	The number of accidents occurring on the road, including the number of deaths and injuries (Albalate et al., 2019). This is related to congestion problems insofar as congestion can increase the likelihood of traffic accidents.	A Bluetooth measurement system: a remote sensor to deduce the occurrence of accidents (Retallack et al., 2019).

	Operating Cost	Additional truck operating cost acquired by the customer because of traffic jams (Lay, 2018)	Operating cost = the additional costs of the further travel time + the additional truck operating costs as a result of stopping, starting and speed variation (Lay, 2018).

Productivity Improvement	Traffic jams (congestion) lead to a reduction in productivity through increasing operating costs, reducing productivity outputs and lessening job creations (Harriet et al., 2013).	The productivity improvement in transportation is measured based on technological adoption, total operating cost, and technical efficiencies (Choi et al., 2014).
Fuel Consumption and Cost	Traffic congestion impacts the consumption of fuel used and consequently leads to an increase in fuel costs (Errampalli et al., 2015).	FC = V+ R+RS+FL+ (P/W) FC = Fuel consumption in ml/km V = Speed in k mph R = Roughness in mm/km RS = Rise in m/km FL = Fall in m/km P/W = Power - Weight Ratio (Errampalli et al., 2015).
Rush Hours	The peak hours where a congestion problem is created (Berisha, 2016)	Journey trip planning applications (Lane, 2019)

2.6.3.2. Road Infrastructure Maintenance

The high demand for freight has been a key driver of recent changes in economic systems at the global, regional, and local levels, due to population expansion in most countries (Litman, 2003). All of these factors have a negative impact on available road infrastructure (Hesse et al., 2004).

Based on previous studies conducted in the road freight transport industry, it has been observed that road freight transport companies face difficulties in effectively controlling quality (Lee et al., 2013), time, and cost. This leads to increases in trip cost and time delays in completing maintenance projects, along with high levels of political influence and corruption (Bruijn, 2007).

Aziz (2006, pp. 3-1) and Bryce (2008) in the Handbook of Highway Engineering pointed out that "road infrastructure development enhances mobility and is critical to the economic growth of a community and a country as a whole." Unfortunately, poorly planned, designed, and constructed highways and roads can exacerbate the conditions of inadequate and weak infrastructure. This has a direct impact on countries not only economically but also environmentally and socially. Road infrastructure development involves innovative road design to maximize highway capacity and minimize emissions produced by vehicles stuck in congestion (Lee et al., 2013).

Salimifard et al. (2012) confirmed that the importance of road transportation is increasing day by day, especially for companies that depend on transporting cargo via road. However, road transport is considered one of the main consumers of petroleum products, thereby contributing directly to greenhouse gases and CO2 emissions. Sustainable transport is suggested by researchers through the use of more environmentally friendly automotive trucks and other sources of gas in order to reduce CO2 emissions in the road freight transport sector (Kumar, 2013).

Innovative road infrastructure systems can help reduce negative impacts on countries' economies and the environment. Road maintenance is a method for increasing the efficiency of the road infrastructure system and improving the country's development (Sultana et al., 2013). It has been observed that poor infrastructure directly impacts countries' economics and the environment as they create noise and pollution, affect public health, lead to trip delays, raise trip costs, and have other land use impacts (Goh & Yang, 2014).

Jha et al. (2014) stated that poor road infrastructure can impede traffic mobility, affect climate change, impact the environment negatively, and limit the number of trips, thereby directly affecting the economy. Therefore, proper road infrastructure coupled with effective maintenance, increased public awareness, and well-considered government regulations all play significant roles in the three aspects of sustainability.

Poor infrastructure has a direct negative impact on economies and the environment, acting as barriers to achieving sustainability in the road freight transport sector (Goh & Yang, 2014).

Another recommendation by Tong et al. (2015) is that accessibility is essential for measuring the performance of road transport systems, calculated by the ability of users and freight trucks to reach desired destinations smoothly. Mobility, or the ease of movement over available road networks, is another measure. Thus, road infrastructure maintenance and appropriate planning lead to improved mobility and directly enhance network accessibility. Increasing the quality of road maintenance is essential for the development of countries (Tsekeris, 2016). Enhancing and developing transportation infrastructures such as roads and bridges to an acceptable level of serviceability could be achieved through the provision of innovative and technological solutions (Linxue et al., 2015).

Broin et al. (2017) highlighted that poor infrastructure and the lack of technological infrastructure lead to poor accessibility, negatively affecting mobility. Moreover, poor infrastructure and damaged roads reduce accessibility and mobility, as seen during events like COVID-19, which negatively impacted the movement of essential goods. Road freight transport companies should initiate marketing campaigns highlighting the importance of road freight transport and its role in a country's economy (Elgazar et al., 2023; Dzinamarira et al., 2020).

Tsekeris (2016) observed that limited attention has been paid to infrastructure network planning, management, and monitoring systems. Safety and operational efficiency can increase by applying technology to reduce accidents and maximize trip quality (Oliveira et al., 2019). Collaboration between the private and public sectors, as well as the government, is advantageous in developing road infrastructure to accommodate the increasing volume and capacity of freight and passengers and to maintain the infrastructure to cope with new innovative technologies (Belenky et al., 2019).

Indeed, road freight infrastructure maintenance is necessary to improve the performance of the road freight transport sector. Poor road infrastructure negatively impacts the sector's performance overall. Road infrastructure maintenance plays a critical role in reducing negative environmental and economic impacts to achieve sustainability (Broin et al., 2017; Dzinamarira et al., 2020). Inappropriate road infrastructure affects road transport performance through increased trip delays and costs, driver performance, increased gas emissions, and traffic congestion (Tong et al., 2015). Road infrastructure and maintenance are principal problems facing the road freight transport sector and impacting the performance of road freight transport companies. The previous sections of this study have highlighted that truck driver performance is affected by the congestion problem and poor road infrastructure (Linxue et al., 2015). Table 2.4 outlines the main performance measurements used to assess the impact of infrastructure maintenance on road

freight transport companies and the various techniques to be used for measuring each of them from economic and environmental aspects.

Table 2.4 Performance Measurement Definitions and the Tools used for Measuring Infrastructure Maintenance from Different Sustainable Aspects

Environmental Aspect	Infrastructure Maintenance		
	Performance Measurement	Definitions	Tools
	Energy Consumption	The road condition has direct effects on energy consumption. Poor infrastructure forces drivers to accelerate and brake during their trip, which increases energy consumption (Franco et al., 2016).	CO_2 emissions from the road are calculated according to vehicle numbers and distance travelled per year by various vehicle types: $Ei = \sum (Vehj * Dj) * Eij, km$. Ei = emission of compound (i); Vehj = number of vehicles per type (j); Dj = distance travelled in a year per different vehicle type (j); Eij, km = emission of compound (i) from vehicle type (j) per driven kilometre (Franco et al. 2016).
	Land Use Impact	Land use impact means the infrastructure land construction for the movement of vehicles and pedestrians, including road highways (Xiong et al., 2018).	Land use patterns can be examined according to certain criteria: 1. Density 2. Connectivity 3. Imperviousness 4. Surface Green space 5. Accessibility (Litman, 2017), or by model extension in an urban area (Qualitative expression) (Gečienė et al., 2016).

	Noise and Air Pollution	Road transport leads to various negative externalities, such as noise and air pollution, which affect sustainable development (Jacyna et al., 2017).	Truck air pollution emission is measured according to miles travelled, distance-based emission tax (OECD, 1997; Jacyna et al., 2017). Noise can be traced through the following instruments: passive noise control - parking space management - high-traffic lanes (Jacyna et al., 2017).
	Public Health	Wasiak et al. (2017) stated that infrastructure development has powered the public health in an indirect way.	Public health is measured through the total number of years of life loss because of rash death and of years survived with a health level reduction, weighed by the significance of the health injury suffered (Wasiak et al., 2017).

Economic Aspect	Infrastructure Maintenance		
	Performance Measurement	Definitions	Tools
	Accessibility Trip Delay Trip Quality	Accessibility can be defined as the amount in which the points of origin and destination are linked and can be measured based on trip time, delay, and quality (Vulevic et al., 2018).	Accessibility can be indicated according to infrastructure quality, trip time, speed, trip cost and delay (Vulevic et al., 2018).

	Security Level Safety Level	Infrastructure and highways always need maintaining and repairing to increase the security and safety levels for truck drivers, vehicles, and passengers (Persia et al., 2016).	Road safety performance indicators are used to quantify the number of accidents occurring due to infrastructure problems or network management. They are a good tool for the daily use of the road highways, which includes the degree of safety, security and service provided (Persia et al., 2016).

The following figures (2.1 and 2.2) summarise the main dimensions and KPIs used to measure the performance of road freight transport companies from the economic and environmental aspects, respectively.

The following section focuses on the role of driver training and qualifications in the development of the road freight transport sector.

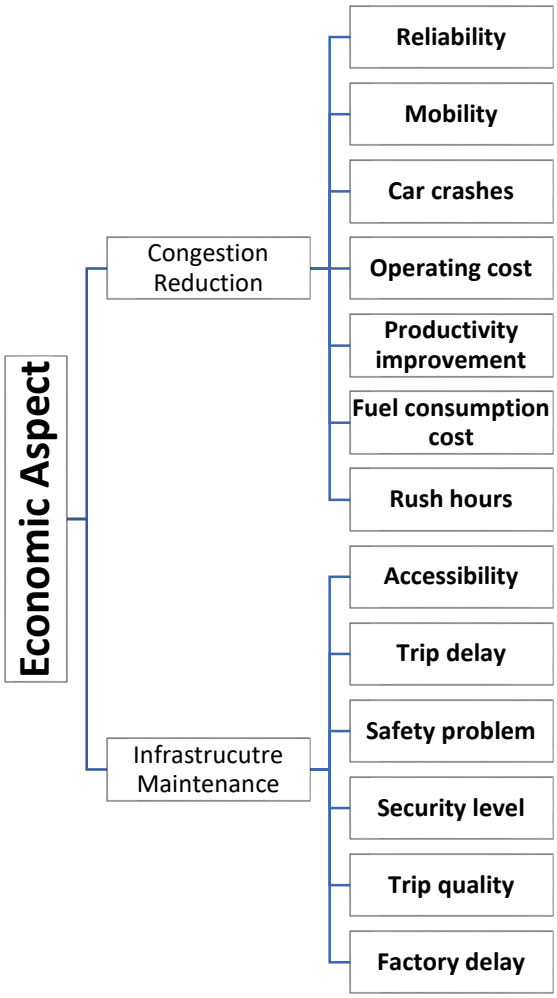


Figure 2.1 The Sustainable Economic Aspect (Dimensions and KPIs)

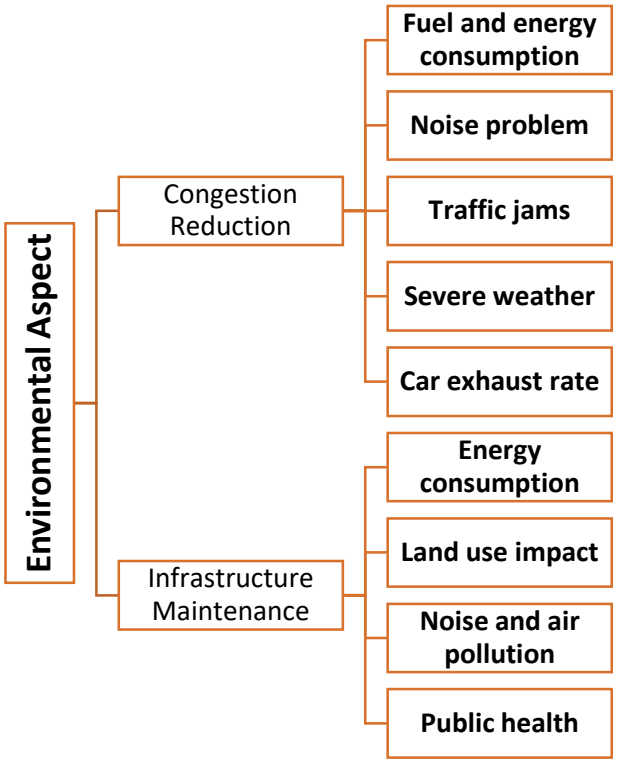


Figure2.2 The Sustainable Environmental Aspect (Dimensions and PMS).

2.6.3.3. Driver Training and Qualifications

Driving is considered one of the most highly skilled jobs, as it requires a high level of professionalism and intuitive speed when problems may arise. Sleepiness is one of the problems affecting driver performance. Since professional drivers are more dependent on transporting hazardous materials, as well as loading and unloading cargoes from factories to their final destination, they might work longer hours, limiting their sleep and causing road accidents (Tzamalouka et al., 2005). Litman & Burwell (2006) agree that driver fatigue has also been identified as a main reason for decreasing safety.

Safety is a critical problem facing truck drivers. Therefore, regulations managing driver working conditions should address the fact that driver fatigue is the main cause of reduced safety levels (Hall & Mukherjee, 2008) (see Figure 2.3).

Crum & Morrow (2002) stated that safety is the main factor affecting truck driver performance and traffic accident rates. However, it is highly recommended that drivers increase their training, and therefore, their level of safety. Additionally, a tracking and monitoring mechanism could be implemented to improve performance on the roads.

In times of crisis, such as the COVID-19 pandemic in 2020, dependence on truck drivers increased for transporting goods, as road transport became a primary mode when air and maritime transport were restricted. However, truck drivers had to face the risks of exposure to infection (Dvorak et al., 2020).

Litman & Burwell (2006) stated that road freight transport plays a key role in countries' economies as it enhances the reliability and quality of the services provided. Goel (2010) confirmed that the European Union has established various rules and regulations to enhance driver working conditions and increase their safety levels. These rules focus on planning driving and working hours while ensuring timely delivery of goods. Furthermore, the EU regulates break and rest stops that drivers should adhere to, based on the journey plan, effectively limiting driving hours. These intentionally restrictive regulations aim to reduce driver fatigue. A secondary problem affecting driver performance is psychological stress caused by external factors, such as congestion problems and severe weather (Kemp et al., 2013).

Professional drivers work under higher levels of pressure and stress to deliver cargo on time, reduce trip time, avoid delays, and increase safety levels from accidents and cargo theft. Driver training should elevate their professional level, with licenses being periodically renewed and random drug testing being conducted (Goel, 2010). These steps would help truck drivers become more professional, which would, in turn, reflect on the incentives offered, required educational levels, and expected professionalism (Sersland et al., 2015).

Zavalko (2018) and Ahmed et al. (2019) suggested that road freight transport companies should focus on driver qualifications and training in the use of various technological applications, especially eco-driving, to track and manage journeys and fuel consumption. Attention should be paid to drivers by training them in technology usage, accident handling, increasing safety, and improving working conditions to prevent driver fatigue (Mehdizadeh et al., 2019). Although different technological applications are available for the road freight transport sector, their global implementation is still lacking. Furthermore, most road freight transport companies lack technological measurement systems to assess their performance (Sousa et al., 2018).

Driver performance is a key dimension for road freight transport companies to achieve sustainability from the social aspect. Consequently, it is the mission of road freight transport companies to enhance their performance by providing drivers with training sessions, and governments should also establish rules and regulations to manage their working conditions (Ahmed et al., 2019; Sousa et al., 2018). Furthermore, poor driver performance is linked to longer working hours, driver fatigue, reduced safety levels, and the influence of alcohol. Therefore, the adoption of technology and innovative solutions is an effective way to reduce the negative impacts facing the road freight transport sector while enhancing the performance of road freight transport companies and achieving sustainability (Mehdizadeh et al., 2019). Table 2.5 outlines the main performance measurements to be used in assessing the impact of driver training and qualifications on road freight transport companies and the various techniques to measure each of them from the social aspect.

Table 2.5 Performance Measurement Definitions and the Tools used for Measuring Driver's Training and Qualifications from the Social Aspect

Social Aspect	Driver's Training and Qualifications		
	Performance Measurement	Definitions	Tools
	Working Hours	Sousa et al. (2018) confirmed that professional truck drivers are exposed to several psychological and physical impacts that directly affect their capabilities and the ability to perform well.	Technological applications are the most efficient tools in controlling and truck driver performance, and include: > APPES, a 2D histogram based on two indicators > Accelerator Pedal Position (APP) > Engine Speed (ES) The selection of indicators exposes data that is related to driving behaviour history and speed tracking according to the km/per hour moved (Carpatorea, 2017).
	Compliance with Traffic Rules		
	Driver Accident Rates		
	Safety		
	Exceeding Speed Limits		
	Driver's Fatigue		
	Working under Pressure and Stress		
	Driver fatigue		
	Use of Controlled Substances and Alcohol	Drivers sometimes use illegal or banned substances while driving in order to make more trips, which negatively impacts their performance (World Bank, 2019).	Random tests for drivers are done in road freight transport companies (World Bank, 2019).
	Training Courses	Training truck drivers is a principal approach for increasing their safety, enhancing their performance, reducing the number of accidents, and improving productivity (World Bank, 2019).	There are various training programs available, such as training for operation of new, innovative vehicles, training for safety in case of accidents and training on dealing with hazardous materials (World Bank, 2019).

Figure 2.3 summarises the main dimensions and KPIs used to measure the performance of road freight transport companies from the social aspect. The following section highlights the role of technology in the road freight transport sector and how it is adopted for enhancement and improvement.

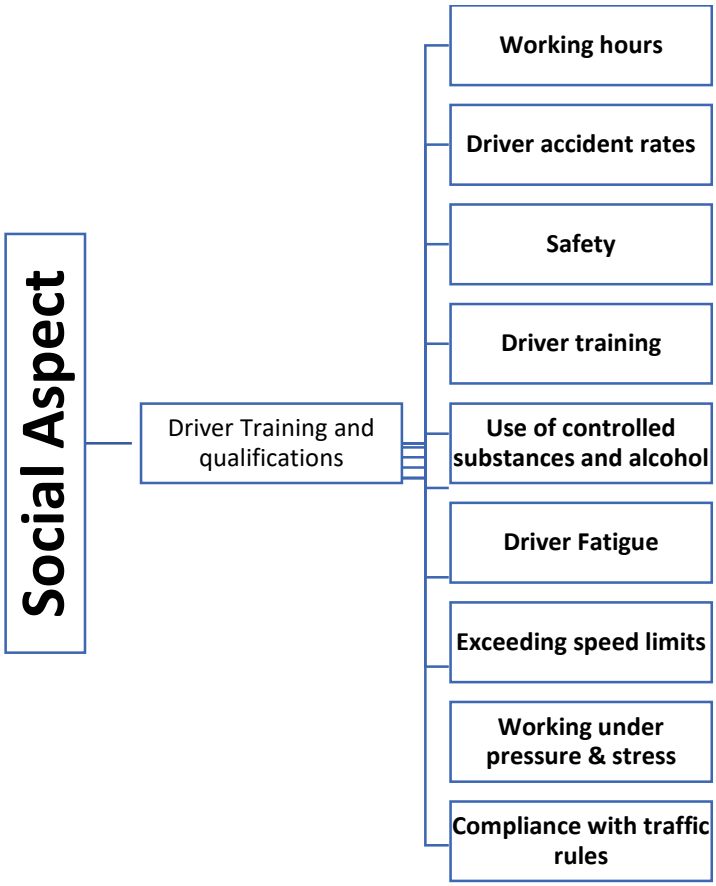


Figure 2.3 The Sustainable Social Aspect (Dimensions and KPIs)

2.6.3.4. Technology in Road Freight Transport

Recently, it has been acknowledged that adopting technologies increases companies' competitive advantage as most companies are competing in a dynamic environment. For that reason, companies usually must look forward to applying new innovative technologies to achieve competitiveness. There is significant technological app development, such as ICT, while their integration and efficient application require substantial investments and well-structured infrastructures (Elgazar et al., 2023; Liang et al., 2016).

In the realm of road freight transport, there exist various specialized technological systems, like navigation systems, that most trucks are equipped with (Nuzzolo et al., 2015). These navigation systems are

supported by tracing and tracking systems, assisting road freight transport companies in monitoring vehicles and drivers during their trips. They provide drivers with essential information, such as estimated time of arrival, alternative routes to bypass congestion areas, and fuel consumption rates (Elgazar et al., 2023; Settey et al., 2019). However, despite the importance of these technological systems, there is still significant progress to be made. For instance, some developing countries lack the necessary infrastructure to effectively support the integration of these technologies. Additionally, various limitations and constraints exist in some areas concerning the usage of innovative trucks equipped with navigation systems (Arentze et al., 2012).

The adoption of e-commerce is currently rare in this sector, despite its potential to enhance overall performance (Nuzzolo et al., 2015). For road freight transport companies to improve transportation performance in the future, they should ideally monitor, and limit emissions generated from road transport. This highlights the need for a predefined performance measurement system that can assess their performance from an environmental aspect. It's important to note that innovative practices are often more expensive than traditional methods, as these solutions are relatively new and require substantial investments (Bonilla, 2016). Additionally, collaboration among different stakeholders, including researchers, governments, and road freight transport company managers, is necessary to implement sustainable and innovative practices. However, this collaboration can present challenges due to potential conflicts of interest when implementing innovative solutions (Elgazar et al., 2023; Holden et al., 2016).

Elgazar et al. (2023) and Arias et al. (2017) primarily focused on regulatory measures recommended by researchers to address the negative environmental impacts of the road freight transport sector, such as traffic congestion and air pollution. To improve any measurement system, technological readiness is required. Therefore, the implementation of communication and information technologies and innovative solutions should contribute value to the road freight transport sector (Roso et al., 2019). However, innovative systems have yet to be fully implemented, and infrastructure development and improvement are still needed. Given the dynamic nature of the road freight transport market, effective management, goal setting, and vision are crucial steps toward achieving corporate objectives. Thus, road freight transport companies should develop and apply a performance measurement system to enhance competitiveness (Elgazar et al., 2023; Settey et al., 2019).

The European Commission aims to use more environmentally friendly sources of energy to reduce gas emissions, particularly as the demand for road freight transport continues to rise. Road transport is a significant contributor to domestic CO2 emissions, accounting for 85% of the total (Litschke & Knitschky, 2012). Consequently, the introduction of innovative practices has the potential to decrease CO2 emissions from the road transport sector, through vehicle fuel efficiency, carbon intensity fuel usage, and optimization of the road freight transport network. In recent years, the development of information and

communication technologies (ICT) has been on the rise, leading to increased adoption of ICT in road freight transport companies to enhance process performance (Elgazar et al., 2023; Li & Yu, 2017; Parihar, 2017).

OECD (2011) suggested various technological support policies to mitigate the negative impacts of gas emissions, such as adopting energy intensity reduction technology by replacing fuels with bioenergy derived from bio-wastes. Additionally, there's a focus on developing and maintaining road infrastructure to utilize new low-carbon technologies. The US Department of Energy (2015) noted that transportation is a major source of gas emissions and pollution. Therefore, adopting technological solutions to gradually reduce these impacts, such as automating vehicles with sensors and using lightweight materials, is useful in achieving the 2050 emission reduction goals (Parihar, 2017).

Elgazar et al. (2023) and Marchet et al. and Perego et al. (2009) emphasized that to enhance road freight transport companies and reduce fuel consumption and carbon dioxide emissions per ton-kilometre, freight apps should be implemented. These apps can be utilized by both cargo owners and drivers. Cargo owners can manage sources of goods and select appropriate drivers, while drivers can identify available trucks and monitor the transportation process. Cargo owner apps can support queries, ordering, tracking, and account management. Logistics companies that own or outsource trucks can use these apps for functions like vehicle archiving, dispatching, and tracking. Driver apps focus on source announcements, goods identification, and transportation process review (Elgazar et al., 2023; Parihar, 2017).

In pursuit of sustainability, governments and road freight transport companies must collaborate to maintain and redesign infrastructure and bridges to accommodate the latest innovative solutions. Additionally, the government should establish rules and regulations to professionally oversee the road freight transport sector (Keeling & Mooney, 2011; Besselink et al., 2016; Tubis & Wojciechowska, 2017; Elgazar et al., 2023). Various practices can contribute to enhancing the overall performance of road freight transport companies, including technology adoption, road freight transport technology development, and raising awareness about the significance of information and telecommunication systems and sustainable development in transportation. These practices should improve flexibility, productivity, quality, susceptibility, resilience, and the reliability of road freight transport chains and activities (Elgazar et al., 2023; Naganathan & Chong, 2017).

Table 2.6 highlights the utilization of technologies in the road freight transport sector, as well as illustrating key problems and limitations.

Table 2.6 The Use of Technologies in Road Freight Transport: Problems and Limitations

Aspect	Area	Problem	Authors	Key Research Findings	Key Research Limitations
Technologies	**Freight Transport Apps and Practices**	Lack of Adoption of Technologies	Amekudzi et al., 2005 Mckinnnon et al., 2007, 2011 Klunder et al., 2009 Marchet et al., 2009 Keeling et al., 2011 Perego et al., 2011 Elgazar et al., 2023	• The role of technology in road freight transport sector has been identified as well as its impact on measuring company performances.	• Limited studies focus on the impact of technologies in mitigating this sector's problems.
			Feng et al., 2012 Litschke et al., 2012 Evangelista et al., 2013 Rodridge, 2013 Elgazar et al., 2023	• Recognising the limitations of adopting technologies in the road freight transport sector	• Limited incorporation of technologies in existing performance measurement systems
			Li et al., 2017 Naganathan et al., 2017 Tobogu et al., 2018 Coulombel et al., 2018 ERTRAC, 2019 Carlan et al., 2019 Rocco et al., 2018 Huang et al., 2018 Settou et al., 2019	• Further suggestions have been recommended to increase implementation of technologies in this sector.	• Lack of testing the relationship between technology utilisation and measuring performance to lessen problems towards sustainability

Figure 2.4. Different types of technological apps and innovative solutions to assist in measuring the performance of road freight transport companies from the sustainable perspective.

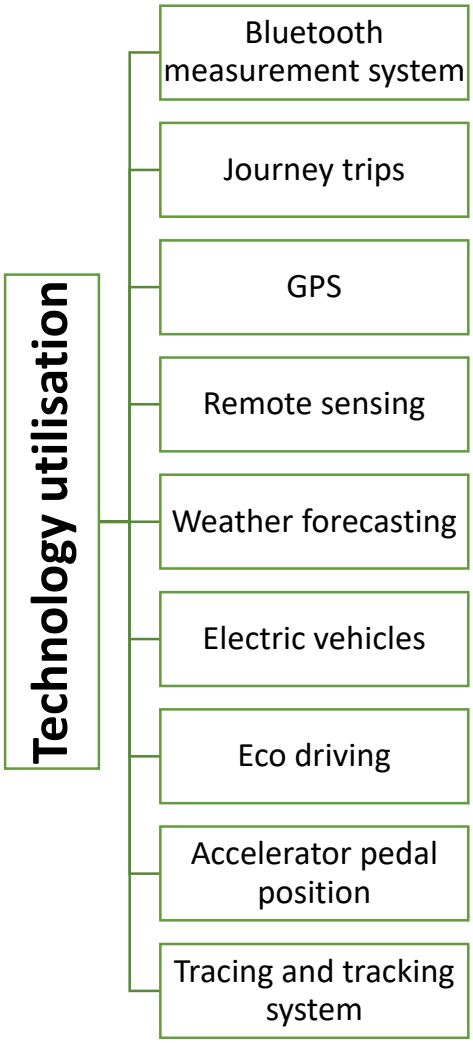


Figure 2.4 Technology Currently Utilised in the Road Transport Sector

To conclude, the road freight transport sector has been chosen as the focus of this research due to the significant increase in the reliance on road transportation for goods. However, this sector faces numerous challenges on a global scale, encompassing economic issues (trip costs, fuel expenses, and operational costs), environmental concerns (air and noise pollution, fuel consumption, and energy usage), and social issues (shortage of professional drivers and subpar working conditions) (Engstorm, 2016; Tubis et al., 2018; Villamizar et al., 2020). Technological applications and innovative solutions have been recognized as viable approaches to address and alleviate these problems, although the effective adoption and implementation of such technologies still lag in many countries (Anwar et al., 2020).

Road freight transport companies find the need to measure their performance at the operational level, not solely at the strategic level. This enables them to pinpoint issues and formulate strategies for their mitigation, thereby enhancing overall performance and achieving sustainability (Noguerol et al., 2018; Havenga & Simpson, 2018). Drawing from an extensive literature review, the key road freight transport challenges from a sustainable standpoint have been identified (refer to Figure 2.5).

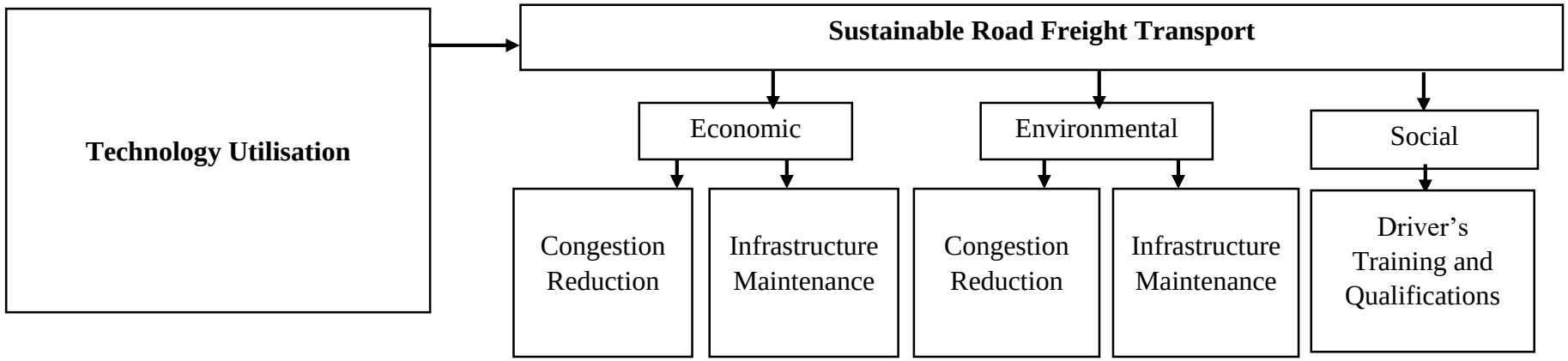


Figure 2.5 Identification of Sustainable Road Freight Transport Problems

2.7. Research Gap

It is well-established that the significance of road freight transport is progressively growing, yet it continues to generate various negative externalities, including congestion, air pollution, and intensified logistics activities (Irigoyen et al., 2018). James (2013) and Bedinger et al. (2016) also underscored road freight transport as a primary contributor to environmental issues. While Tob-ogu et al. (2018), Lindh et al. (2018), and Stojanovic (2017) emphasize the necessity for effective establishment and maintenance of road infrastructure, there persists a lack of technology adoption in this sector, with many drivers being unwilling to embrace the available technologies.

Until now, a dearth of reliable performance measurement systems has been observed in the road freight transport sector. Additionally, there is a deficiency in quantifying actions and incorporating sustainable performance measurements within road freight transport companies (Curtis et al., 2017; Saunila, 2018; Landstorm et al., 2018; Franceshini et al., 2019).

As elucidated in the preceding section, the review has unveiled that existing road freight transport PMSs suffer from inadequate integration of the three sustainable aspects. Many of these systems exclusively focus on one or two aspects, overlooking a holistic approach (Campos et al., 2019). Moreover, the current PMSs predominantly address sustainable transport performance from a strategic standpoint, neglecting the operational level (UNCTAD, 2017). Furthermore, there is a conspicuous absence of the incorporation of technological and innovative practices to address sustainability concerns (Bedinger et al., 2016). This forms the basis for highlighting the research's contribution to knowledge in section 2.6.2 and serves as the groundwork for formulating and testing the research proposition: "Assessing Road freight transport performance using a sustainable performance measurement system, through the integration of technologies, should enhance the operational performance of road freight transport companies from diverse sustainable perspectives (economic, environmental, social)."

Consequently, this research addresses the following gaps:

Existing performance measurement systems lack the inclusion of road freight transport problems from the perspective of the three sustainable aspects (economic, environmental, and social) and their respective impacts.

The integration of technology and the adoption of innovative practices, alongside the three sustainable aspects, have yet to be realized within a unified road freight transport performance measurement system.

The incorporation of a comprehensive set of performance measurements from a sustainable perspective, to serve as Key Performance Indicators (KPIs) for measuring road transport company performance at an operational level, remains unexplored.

To bridge these gaps, the primary objective of this research is to develop a performance measurement framework tailored specifically for road freight transport companies. This framework aims to assist these companies in monitoring their performance, facilitating the integration of technological advancements, and enhancing their decision-making towards sustainability. To achieve this research objective, the following research questions have been formulated:

Q1. What sustainable perspective-related challenges does the road freight transport sector encounter, and how do these challenges affect the operational efficiency of companies involved in road freight transportation?

Q2. To what extent can technology adoption aid in mitigating the challenges confronting the road freight transport sector and contribute to achieving sustainability?

Q3. What key elements must be integrated when developing a performance measurement framework for a road freight transport company?

Q4. What potential challenges could road freight transport companies encounter when adopting the developed road freight transport performance measurement framework?

Q5. How can road freight transport companies surmount these challenges?

This research will centre on exploring the relationship between the developments of a road freight transport performance measurement system from the lens of sustainability. Technology integration will be a pivotal aspect under investigation to assess its impact on different components of the devised performance measurement system. The goal is to aid road freight transport companies in addressing their existing issues and enhancing their operational performance, as discussed earlier.

2.8. The Developed Road Freight Transport Performance Measurement System

Performance measurement has garnered significant attention from both researchers and practitioners, as it has been substantiated that measuring, quantifying, modelling, reporting, and strategizing road freight transport performance can aid road freight transport companies in identifying problems, challenges, and ultimately enhancing their operational performance (De Bod et al., 2016). As a result, this section introduces a newly developed road freight transport performance measurement system.

2.8.1. Research Variables

Based on previously conducted studies, it has been observed that a single dimension can have an impact on multiple aspects of sustainability. For instance, Rodrigues et al. (2010) proposed that congestion can affect both the environmental and economic performance of road transport. Khanal (2012) stated that traffic congestion has a direct negative impact on the environment, leading to increased operational costs and reduced productivity. Congestion not only directly affects environmental and economic performance but also indirectly influences social performance by elevating stress levels for drivers and road users (Demir et al., 2015). Taylor (2008) noted that this issue further ripples into social and economic activities at the operational level. Boussier et al. (2011) concurred that congestion hampers economic performance and logistical systems' efficiency. Grote et al. (2016) emphasized that congestion directly contributes to environmental degradation and affects surrounding areas.

Ruli (2016) highlighted that traffic congestion affects not only the environment but also the social aspect. However, Figliozzi (2011), Meng & Liu (2012), and Kok et al. (2012) firmly asserted that congestion undermines all three pillars of sustainability, hindering their achievement. This is analogous to road and infrastructure maintenance, as some authors contended that this aspect exclusively impacts the economic dimension (Sultana et al., 2012; Hesse et al., 2004; Lopez et al., 2008; Schoenmaker et al., 2016; Linxue et al., 2015; Bruijn 2007; Tang et al., 2015). Conversely, others, like Bryce (2008), Goh et al. (2014), Meng (2015), and Salimifar (2012), insisted that road infrastructure and maintenance influence all three dimensions.

Kumar (2013) asserted that congestion significantly impacts the environment by contributing to noise and air pollution, a sentiment echoed by Lee et al. (2013), who added that it also raises driver stress levels, thereby affecting the social dimension. Concerning driver qualifications and training, all researchers addressing this aspect have confirmed its primary importance within the social dimension (Litman et al., 2006; Randall et al., 2008; FMCSA, 2011; Cantor et al., 2009; Kemp et al., 2013; Kuiken et al., 2001; Mayhew, 2007; Beanland et al., 2012).

Technology plays a pivotal role in achieving sustainability within the road freight transport sector, enabling managers, cargo owners, and drivers to search for cargo, track shipments, and reduce gas emissions (Keeling & Mooney, 2011; Li & Yu, 2017; Elgazar et al., 2023). This is exemplified through the use of renewable resources to replace fossil fuels and the utilization of recycled tools (Naganathan & Chong, 2017). Additionally, the adoption of electric trucks could contribute to achieving sustainable development by 2030, considering road transport contributes to two-thirds of global gas emissions (Rocco et al., 2018; Settou et al., 2019).

Furthermore, the implications of Information and Communication Technology (ICT) should play a pivotal role in mitigating negative environmental impacts, including the use of smart vehicles and GPS. Another technology aimed at reducing the adverse effects of road freight transport is eco-driving, which assists in managing individual driving styles and acceleration patterns (Huang et al., 2018).

Building upon the preceding discussion, the research variables have been identified. The independent variable is the use of technology, with the impact of various technological applications being tested on sustainable road freight transport (dependent variables). (Refer to Figure 2.6). Consequently, the research hypotheses are formulated.

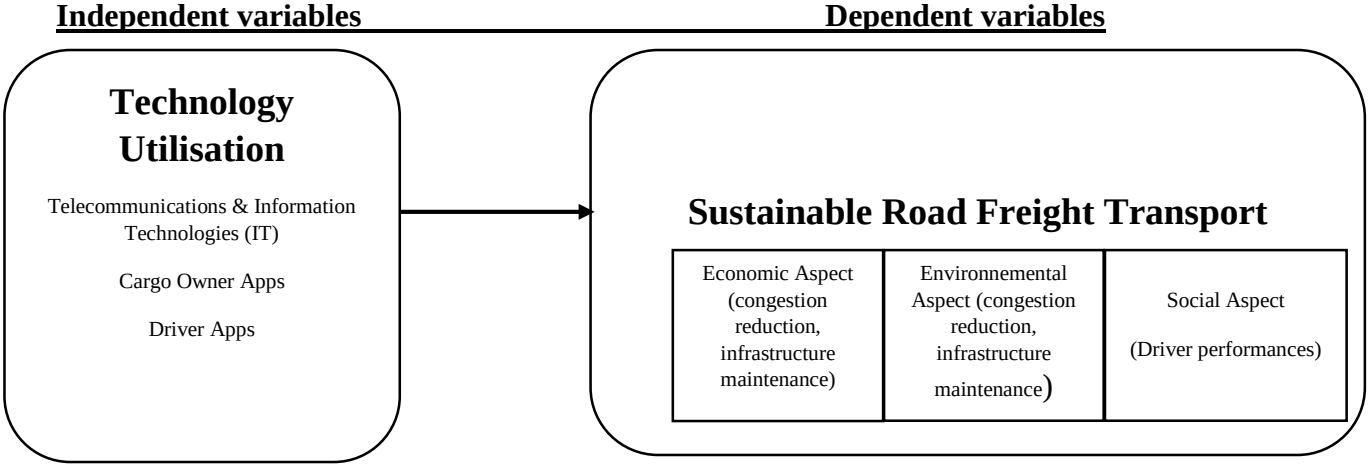


Figure 2.6 The Identification of the Research Variables

2.8.2. Research Hypotheses

The research hypotheses are as follows:

"Adoption of technologies embedded with elements captured in a performance measurement system causes an enhancement in the performance of road freight transport companies towards sustainability (economic, social, and environmental)".

Following a comprehensive literature review and an examination of previous studies in the fields of sustainability, performance measurement, road freight transport importance, and road freight transport performance measurement systems, it becomes evident that the utilization of technology, such as apps designed for cargo owners and drivers (Campos et al., 2019; Carlan et al., 2019), is likely to mitigate negative impacts within the road freight transport sector, including noise, air pollution, congestion, traffic accidents, increases in logistics costs, and driver training and qualifications (Mommens et al., 2016; Karla et al., 2018; Santen, 2013; Russo et al., 2016). These challenges are directly linked to the three sustainable aspects: economic, environmental, and social dimensions (Li et al., 2017).

Furthermore, the current absence of an integrated performance measurement system that combines technology apps with the three sustainable aspects (economic, social, and environmental) within the sector has been identified (Zhang et al., 2015; Sternad et al., 2019). The reduction of these adverse impacts is expected to enhance the performance of road freight transport companies, increase their competitiveness, and facilitate the achievement of sustainability goals (Merchan et al., 2019; Li et al., 2017) (see Figure 2.3).

$H_{1.}$ "An increase in technology adoption leads to an improvement in the economic aspect".

The term "technology adoption" encompasses telecommunications and information technologies, cargo owners' apps, and driver's apps, whereas the "economic aspect" pertains to congestion reduction and infrastructure maintenance.

Mckinnon et al. (2010) and Noguerol et al. (2018) have underscored that trucks and cars could exert a negative influence on the road freight transport sector from an economic standpoint. These adverse effects encompass congestion, accidents, increases in logistics costs, and fuel consumption. Consequently, by employing cleaner vehicles, embracing technological apps, and employing performance measurement techniques involving quantifiable actions (Zhang et al., 2015; Santen, 2013; Burkouskis, 2008), the mitigation of these negative impacts and an enhancement in the economic aspect are anticipated (Atz et al., 2019; Noguerol et al., 2018) (refer to Figure 2.3).

$H_{2.}$ "An increase in technology adoption results in an enhancement of the social aspect".

The term "technology adoption" encompasses telecommunications and information technologies, cargo owners' apps, and driver's apps, whereas the "social aspect" pertains to driver performance.

There exist several road freight transport challenges that exert a detrimental influence on the road freight transport sector from a social standpoint. One of these challenges is the shortage of qualified drivers (Russo et al., 2016). By employing innovative solutions, such as journey planning apps and performance measurement techniques involving quantifiable actions (Zhang et al., 2015; Santen, 2013; Burkouskis, 2008), it is anticipated that these adverse impacts could be mitigated, leading to an enhancement in the social aspect (Schulte et al., 2018; Noguerol et al., 2018) (refer to Figure 2.3).

$H_{3.}$ "An increase in technology adoption leads to an improvement in the environmental aspect".

The technology adoption refers to telecommunications and information technologies, cargo owners' apps, and driver's apps, while the environmental aspect pertains to congestion reduction and infrastructure maintenance. Mommens et al. (2016) and Karla et al. (2018) have highlighted various road freight transport problems that negatively impact the road freight transport sector from an environmental perspective, such as congestion, accidents, health issues, and fuel emissions. Therefore, through the

utilization of innovative vehicles, adopting technological apps, and measuring performance by quantifying actions (Zhang et al., 2015; Santen, 2013; Burkouskis, 2008), these adverse effects are expected to be mitigated, leading to improvements in the environmental aspect (Schulte et al., 2018; Noguerol et al., 2018) (see Figure 2.3).

2.8.3. The Developed Road Freight Transport Performance Measurement Framework

Abbasi & Nilsson (2012) and Carvajal & Ayush (2018) have stated that sustainable transport development primarily aims to advance economic and social gains while concurrently reducing negative environmental impacts.

Road freight transport plays a significant role both internationally and domestically, connecting neighbouring countries and facilitating the transportation of various types of cargo between points. However, Pison (2018) emphasizes that lack of control in road transport within the freight sector leads to concerns over unpredictable journey times, high logistics costs, congestion, and elevated levels of pollution and greenhouse gas emissions (Lindh & Rudeke, 2018).

Journey time can be influenced by various factors, including unpredictable customs procedures and congestion in and around urban areas. For these reasons, technologies are likely to reduce the social, economic, and environmental impacts of freight transport to some extent and contribute to a sustainable future. Nevertheless, previous studies have not yet fully integrated the three main aspects of sustainability (economic, social, and environmental) with technologies embedded as a key supporting factor for road freight transport companies to address operational-level challenges.

Building upon previously conducted studies on road freight transport, a road freight transport performance measurement system is developed through the lens of sustainability by identifying the main dimensions and required KPIs.

In conclusion, a performance measurement system has the potential to significantly enhance a company's overall performance. However, in the road freight transport sector, a consistent and effective integration of such a system has yet to be realized. Such a system would not only provide value to individual road freight transport companies but also contribute to the entire industry and enhance competitiveness. Consequently, a road freight transport performance measurement framework has been developed (see Figure 2.7).

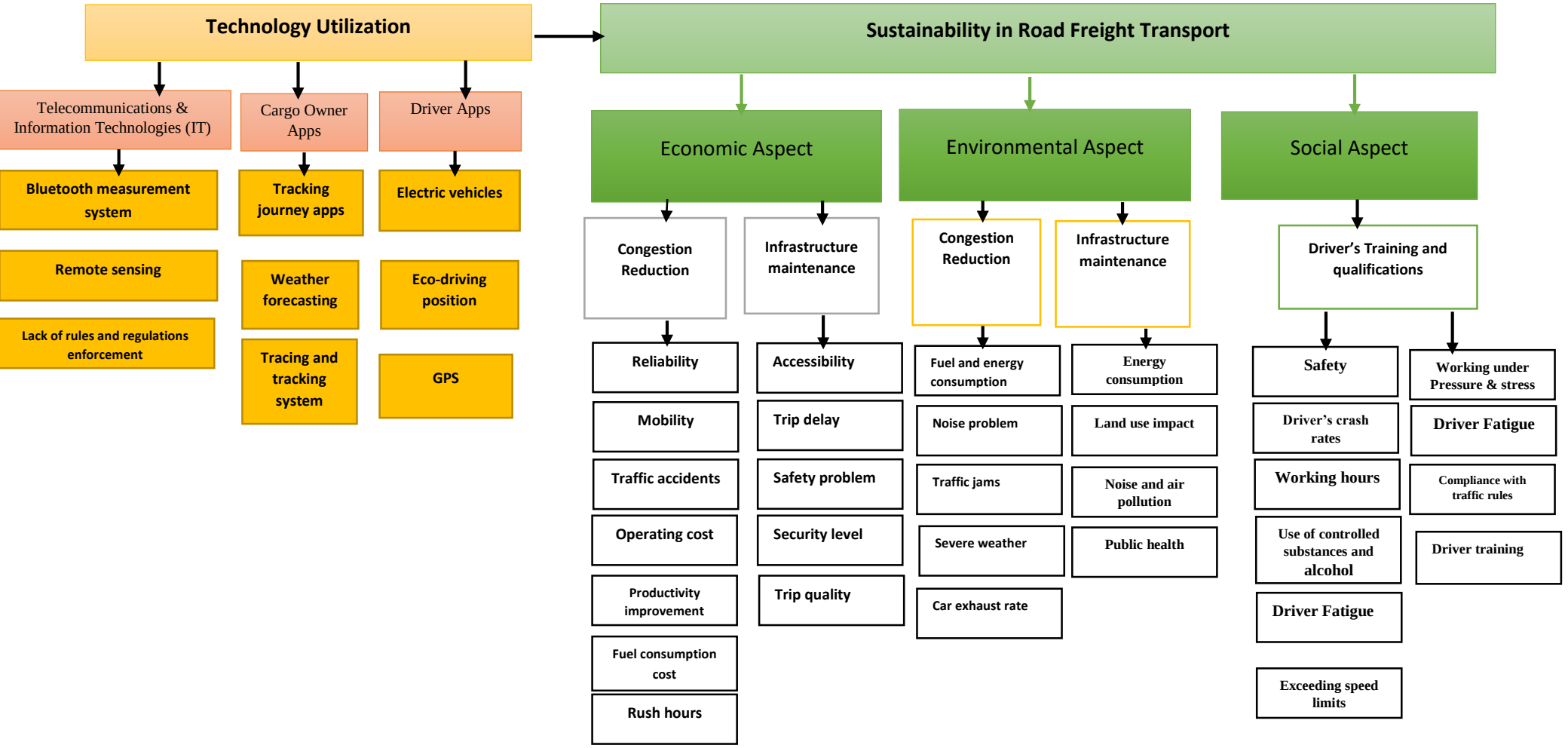


Figure 2.7 The Proposed Road Freight Transport Performance Measurement Framework extracted from the Literature Review

To date, and based on previous discussions and reviewed papers, a research gap has been identified, demonstrating a limited presence of performance measurement systems, particularly for road freight transport companies at the operational level. Therefore, the proposed system aims to address this gap by integrating the three sustainable aspects with technologies. This integration will facilitate the measurement of road freight transport companies' performance on this level, enabling the identification of impacts related to the recognized problems. This, in turn, will assist road freight transport managers in proposing solutions and mitigating these issues to achieve sustainability.

It's also evident that existing sustainable freight performance measurement systems encompass measurements designed for evaluating the freight transport sector at a strategic level, along with corresponding policy implementations. However, there is a noticeable scarcity of studies that delve into sustainable road freight transport performance on the operational level.

Furthermore, the identified problems manifest with diverse sustainable aspects. For instance, congestion problems have both environmental and economic impacts, directly and detrimentally affecting road freight transport companies' performance. Moreover, there's a lack of incorporation of technologies within the different elements encompassed by existing performance measurement systems. As a result, a developed road freight transport performance measurement system has been established, integrating the three sustainable aspects alongside technologies. Additionally, a set of performance measurements has been identified to serve as key indicators for gauging the performance of various road freight transport companies.

2.9. Summary

In conclusion, road freight transport has been the backbone of countries' economies. However, significant challenges have beset the road freight transport sector, giving rise to negative externalities across various sustainable dimensions. These include environmental impacts like pollution and noise, as well as congestion issues and infrastructure maintenance. Notably, congestion and infrastructure upkeep have been identified as critical economic challenges too, affecting operational costs, trip expenses, and fuel consumption. Meanwhile, the social dimension highlights driver training and qualifications as key hurdles.

It is important to acknowledge that while technology adoption could play a vital role in mitigating these challenges and enhancing sector performance, its implementation by road freight transport companies is hampered by high costs. Furthermore, the quantification and measurement of performance can empower these companies to pinpoint issues and bolster their sustainability efforts.

Despite the existence of performance measurement systems, a distinct absence prevails when it comes to a system tailored for road freight transport companies that integrates the three sustainable aspects with technology utilization. This research endeavours to bridge this gap by constructing a performance measurement system specifically for road freight transport companies, viewed through the lens of sustainability and hinged on effective technology incorporation.

The underlying objective of this developed performance measurement system is to quantitatively gauge the processes of road freight transport companies, identifying challenges and areas of improvement. Moreover, it aims to define a set of performance measurements that can serve as key performance indicators (KPIs) for diverse road freight transport entities. The subsequent chapter delves into the research methodology, encompassing the research philosophies, methods, and tools employed to gather the necessary data.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Introduction

In the previous chapter, a road freight transport performance measurement system, viewed through the lens of sustainability, was developed. The PMS is constructed based on prior studies conducted in the field of road freight transport and an analysis of the road freight transport industry worldwide, with a specific focus on Egypt, where the empirical study for this research took place.

This chapter outlines the methods adopted in this research, defining the most suitable research philosophy, approach, and strategy. This is followed by an interpretation and discussion of the research phases employed.

The chapter is organised as follows: The initial section concentrates on presenting the research philosophies, strategies, and approaches, culminating in the selection of the most appropriate ones for utilisation. Subsequently, a comparison between qualitative, quantitative, and mixed methods is provided, highlighting the method most suited for this research.

Following that, the research design is outlined based on the research proposition, research questions, and formulated research hypotheses. The subsequent section delves into the research phases implemented in this study. The research's reliability and validity are presented in Section 3.6, followed by an exploration of research limitations and a discussion on potential strategies to mitigate these limitations.

Finally, the chapter concludes by summarizing key points and insights.

3.2. Research Philosophy, Strategy and Approach

According to Saunders et al. (2012), Flowers (2009), and Saunders et al. (2019), epistemology primarily focuses on the acquisition of valid knowledge within a particular field of research study. In this context, epistemology is chosen because the principal objective of this research is to formulate a road freight transport performance measurement system from the perspective of sustainability. This system is devised based on the comprehensive literature review and an analysis of the road freight transport industry. Additionally, a set of research questions is formulated, aiming to provide well-founded responses rooted in the researcher’s proposed hypotheses, which are derived from prior conducted studies.

Epistemology encompasses two distinct philosophies: interpretivism and positivism. These philosophical stances emphasise the significance of recognizing diverse roles among individuals as social actors. Researchers who opt for an interpretivist philosophy must adopt a hypothetical stance, as the key challenge lies in delving into the social realm of participants, unveiling and comprehending their world from their unique viewpoints. Interpretivism aligns with a post-positivist (inductive) philosophy, given the acknowledged distinction between natural and social sciences. Within the social domain, it is contended that individuals and groups construe situations based on their individual experiences, memories, and expectations (Saunders et al., 2019).

Contrastingly, positivism (deductive) centres around generalisation through empirical study, conducted to assess a theory. Consequently, a positivist approach is conceived and substantiated based on theory, followed by validation using diverse methodologies such as surveys, interviews, or case studies. In quantitative studies, the theory is applied deductively, aligning with the proposed study, aiming to test or verify a theory rather than developing it. Therefore, the researcher formulates a theory, gathers data for testing, and establishes its affirmation or negation based on the outcomes (Creswell et al., 2017). This theory then serves as a framework for the entire study, functioning as a structured model for research questions, hypotheses, and data collection procedures. Positivism and interpretivism methods exhibit compatibility, both emphasising the significance of appreciating and interpreting field data through inductive or deductive reasoning (Rechberg, 2018).

In this research, positivism is employed as it captures the researcher's proposed hypotheses, conducts data collection to evaluate them, and subsequently corroborates or disproves them through results, linking them to the research topic and addressing the formulated research questions. Table 3.1 highlights the core distinctions between interpretivism and positivism, as well as identifying the most appropriate approach and research methodology respective to each of them.

Table 3.1 The difference between Interpretivism and Positivism

Interpretivism	Positivism
Exploring a new idea	Explaining data from the previous conducted studies
More suitable for qualitative research	More suitable for quantitative research
Inductive approach	Deductive approach
Used in developing qualitative theory or design. (building theory)	Used in testing hypotheses or validating research questions. (testing theory)

Source: Adopted from Saunders et al. (2012); Creswell et al. (2017)

Up until this point, the distinctions between interpretivism and positivism have been elucidated in relation to the types of research and the methodologies employed. The subsequent section centres on delineating the disparities among research approaches, ultimately presenting and deliberating upon the chosen approach for this specific research.

3.2.1. Deductive vs. Inductive Methods

Creswell et al. (2017) has elucidated the disparities between the two primary methods of reasoning: the deductive and inductive approaches. Inductive methods proceed from specifics to the general, while deductive methods initiate from the general and culminate in specifics.

Creswell et al. (2017), along with Burney & Saleem (2008), have posited that a deductive researcher embarks on a "top-down" trajectory, commencing from theory to hypotheses, followed by data analysis to corroborate or refute the theory (p. 23). In contrast, an inductive researcher follows a "bottom-up" approach, utilizing participants' perspectives to formulate broader themes and construct a theory by interlinking these themes (p. 23). Furthermore, inductive reasoning is apt for arguments grounded in experience or observation, while deductive reasoning is more suitable for arguments rooted in laws, regulations, or widely

accepted principles. It's worth noting that there exists some divergence among researchers regarding the optimal approach to adopt when conducting research and collecting data.

In fact, two distinct research methods are employed: the deductive approach, centred on theory testing to draw generalized conclusions, and the inductive approach, primarily concerned with theory construction by deriving insights from participants' data before formulating a new theory. Consequently, the forthcoming sections expound upon the disparities between these two approaches and the implications arising from these distinctions.

3.2.1.1. Deduction: Testing Theory

Deduction requires the development of a theory that is subjected to accurate testing. As a result, it is the primary research approach in natural sciences, as laws provide the basis for explaining phenomena, predicting their occurrence, and subsequently allowing for their control (Collis & Hussey, 2009).

Robson (2002) stated that research adopting the deductive approach should follow the following five main steps:

- Formulating a hypothesis (testing the relationship between two or more concepts or variables) derived from the theory.
- Measuring the extent of relationships between the derived variables or concepts.
- Testing these variables or concepts using one or more research techniques, such as focus groups or case studies.
- Concluding and analysing the main outcomes, which will either confirm the theory or indicate the need for modification.
- Modifying the theory in light of the findings.

Deduction possesses several key characteristics. Firstly, it involves seeking a theory that illustrates causal relationships between identified variables. Secondly, deduction necessitates quantifying the theory in a way that enables facts to be measured and expressed quantitatively. The final characteristic of deduction is generalization, which involves selecting samples according to the population size (Saunders et al., 2012).

3.2.1.2. Induction: Building Theory

In research using the induction method, the primary concern is the context in which events are occurring. Similar to the deductive approach, this type of study benefits from a small sample, as it is more likely to be suitable than a larger sample size. Furthermore, researchers following this method should rely more on qualitative data rather than quantitative data. This type of research employs various methods to collect this data, aiming to construct different perspectives of the phenomena (Easterby-Smith et al., 2002; Saunders et al., 2012). Table 3.2 summarizes the differences between the deductive and inductive approaches to research.

For this research, in order to provide explicit answers to the research questions and achieve the research aim, specific steps from testing theory to generalization need to be clarified and followed. For instance, conducting a literature review based on previous studies in the road freight transport industry, analysing the current global situation of the industry, and gathering experiences and observations from various participants. Understanding different viewpoints of participants in the road freight transport industry is essential for generalizing the developed road freight transport performance measurement system. This research focuses on testing and measuring the relationship between different variables identified from the literature review, using various research methods such as surveys and interviews.

It should be noted that explanatory data analysis starts by analysing previously conducted studies and the theory upon which the collected data and relationships between variables are tested (deductive approach) (Saunders et al., 2019). On the other hand, exploratory data analysis first involves collecting and examining data, followed by a discussion of previous studies and theory (inductive approach) (Creswell et al., 2019).

In order to enhance the performance of road freight transport, it has been determined that a deductive approach, as well as explanatory mixed methods, are most suitable for the task, supported by previous studies conducted in this area (Elgazar et al., 2023; Abbasi & Nilsson, 2012).

The deductive approach is selected as it is more suitable for this research and aids in fulfilling the research aim and objectives. Explanatory data is utilized to illustrate theory and previous studies, carried out initially to develop a road freight transport performance measurement system. Subsequently, data is collected to investigate the current situation of the road freight transport sector in Egypt. This is followed by conducting surveys to test the relationships between the variables of the developed performance measurement system. The research

variables are the impact of technology utilization (independent variable) on the sustainable aspects; economic, social, and environmental (dependent variables) (see Table 3.2). The upcoming section identifies the differences between qualitative and quantitative methods and specifies which type is utilized within this research.

Table 3.2 The differences between Deductive and Inductive Approaches to Research

Deductive Approach	Inductive Approach
Focuses more on scientific principles and theories	Focuses more on gaining an understanding of humans and events
Starts from moving from theory to data	Starts from moving from data to theory
Needs an explanation of causal relationships between variables	Needs a close examination of the research context
Is more suitable for collecting quantitative data	Is more suitable for collecting qualitative data
Follows the application of various data collection methods to ensure the validity of the data	Has a more flexible structure to allow changes of research emphasis.
Quantifies and measurement variables to ensure the clarity of data	Realises that the researcher is a part of the research process
Requires selecting sufficient samples according to the population size in order to generalise conclusions	Requires a smaller number of sample size, as there is no need for generalisation

Source: Adopted from (Saunders et al., 2012)

3.2.2. Qualitative vs. Quantitative Methods

Creswell et al. (2009) noted that the distinction between qualitative research and quantitative research is manifested through the use of words in qualitative methods as opposed to numbers in quantitative methods. This contrast extends to the types of questions asked, such as open-ended questions in qualitative approaches and closed-ended questions in quantitative interviews. Consequently, in research, the fundamental philosophical assumptions are established, and the research strategies are outlined to determine the most suitable method whether quantitative experiments or qualitative case studies. The specific methods involved in conducting the research, such as collecting data quantitatively or gathering qualitative data through observations, are also defined.

There are three distinct research approaches: qualitative research, quantitative research, and mixed methods. In reality, these three approaches are not as distinct as they might initially appear, as a study can lean more toward being qualitative or quantitative. Mixed methods research occupies a middle ground, incorporating both qualitative and quantitative methodologies (Mckim, 2017) (see Table 3.3).

In quantitative research, data is often translated into numerical values using statistical analysis to explore relationships between known variables and those discovered through research. To collect and analyse quantitative data, a strong understanding of the connections between variables is necessary, achieved through descriptive or inferential methods (Trochim et al., 2001). Quantitative analysis relies on logical reasoning, evidence, and argumentation. Researchers are responsible for gathering data from participants and then analysing them, either by identifying common themes or by summarizing participants' perspectives using expressive and influential language (Azorin, 2016; Creswell et al., 2009).

Qualitative research involves the researcher relying on participants' viewpoints, formulating broad and general questions, and collecting data primarily composed of words (or texts) from these participants. The subsequent steps involve describing and analysing these words to extract themes and address research questions. This method demands significant time in the research field to collect data, transcribe them, and perform analysis (Creswell et al., 2009). Consequently, conclusions evolve and develop as more data are gathered. Qualitative research also employs inductive reasoning, progressing from specific observations of individual occurrences to broader generalizations and theories. Exploratory findings may later lead to overarching conclusions or theories (Mckim, 2017).

Creswell et al. (2017), Burney & Saleem (2008), Creswell et al. (2009), and Biber (2015) have affirmed that both qualitative and quantitative research make assumptions about the same elements within the research process. The differences between these methods primarily stem from how researchers execute each step. It is important to note that the contrasts between qualitative and quantitative methods are not opposites; they are distinct. No study is strictly quantitative or qualitative; instead, each method shares many core elements. These include the research's focus and objectives, the application and handling of literature, the methods of data collection and analysis, and the procedures used to test and validate collected data. Table 3.3 outlines the distinctions between the three research methods: qualitative, quantitative, and mixed.

Table 3.3 The difference between Qualitative, Quantitative and Mixed Approaches

Quantitative Methods	Mixed Methods	Qualitative Methods
Testing research questions or hypotheses quantitatively	Using qualitative and quantitative research methods for testing research questions and hypotheses	Formulating open-ended questions to gain participants' points of view
Using statistical tools for converting data into numerical data	Utilising statistical tools and text analysis for analysing data	Utilising interviews and observation data for analysing data and creating themes
Measuring the relationships between research variables	Concluding numerical data, in addition to creating themes based on the participants' points of view	Expressing participants' words and developing research themes

Source: Adopted from (Creswell et al., 2009)

In this research, qualitative methods are integrated through the use of semi-structured interviews to illuminate the current issues and conditions within the road freight transport industry. These interviews also aim to gather participants' insights regarding the role of technology adoption in enhancing the road freight transport sector (Creswell et al., 2009). Participants' statements are organized into themes to facilitate the development of clear answers to the research questions. Focus groups are conducted to demonstrate the feasibility of the developed road freight transport performance measurement system (Bengtsson & Fynbo, 2018).

On the other hand, quantitative methods are employed through surveys to capture participants' opinions concerning the developed road freight transport performance measurement system. The collected results are then analysed and converted into numerical data for testing the relationships among the identified research variables (Mann, 2016; Hair et al., 2014).

The research gap is identified, and research questions and hypotheses are formulated in Chapter Two (see Chapter Two). The research proposition is as follows: "*Assessing Road freight transport performance using a sustainable performance measurement system through the integration of technologies should enhance the operational performance of road freight transport companies across various sustainable dimensions (economic, environmental, and social).*"

This research proposition is designed to bridge the research gap by combining sustainability, performance measurement, and the economic role of road freight transport. The research follows a positivism philosophy to test the road freight transport performance measurement system developed from the literature review.

A deductive approach is employed in this research, starting with a discussion of the theory, and concluding with a proposed road freight transport performance measurement system. Subsequently, the necessary data is collected to showcase its applicability within road freight transport companies. To affirm the research proposition and provide clear responses to the research questions, a mixed methods approach is adopted. This involves a qualitative approach (via interviews) to identify the performance metrics to be incorporated into the developed framework, and a quantitative approach (through surveys) to examine the relationships among the identified research variables (see Figure 3.1).

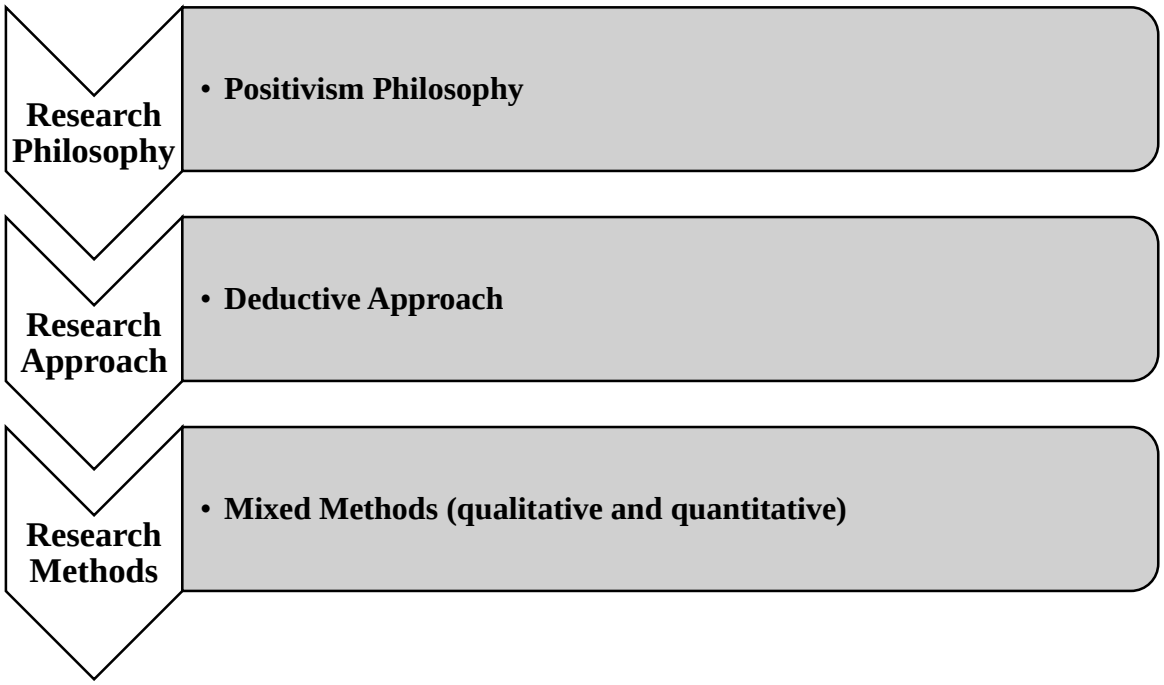


Figure 3.1 Research Philosophy, used Approach and Methods

3.3. Research Design

In this section, the design of this research is outlined, including the description of data collection methods, the time horizon, and the sampling size and approach.

3.3.1. Data Collection Types

For this research, data were collected from both secondary and primary sources. Secondary data encompassed previous studies conducted in the fields of road freight transport, sustainability, and performance measurement, along with an analysis of the road freight transport industry through reports, statistical data, and records. Primary data, on the other hand, were obtained directly from various experts within the road freight transport industry, including practitioners and academics.

Qualitative data was gathered through the use of semi-structured interviews, which aimed to explore the current state of the Egyptian road freight transport sector. Focus groups were then conducted to ascertain the performance measurement aspects to be integrated into the developed framework, thereby demonstrating the applicability of the road freight transport performance measurement system.

Quantitative data collection involved the administration of surveys to examine the relationships among the identified variables.

3.3.2. Time Horizon

A cross-sectional time horizon is utilised in this research, as the research is conducted for a specific time using an empirical study and surveys to fulfil the main aim desired (Creswell et al., 2019) (See figure 3.2).

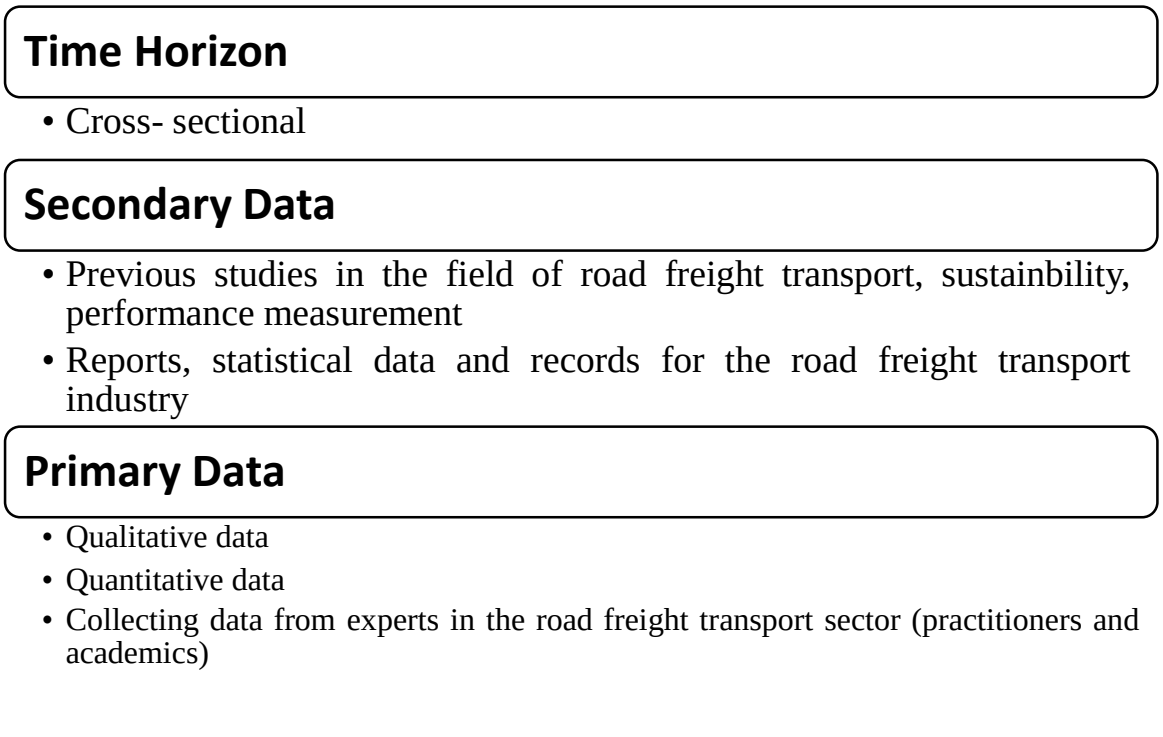


Figure 3.2 Research Methods

3.3.3. Sampling

Different tools have been employed for data collection in this research. First, semi-structured interviews were conducted, involving both academics and practitioners as participants. The academic participants were selected from the field of road freight transport and performance measurement. Practitioners, on the other hand, were chosen by reaching out to various professionals within the Egyptian road freight transport sector, including top-tier managers, logistics and transport managers, quality managers, and professional truck drivers.

Subsequently, a survey was utilized to validate the developed road freight transport performance measurement system and to assess the relationships among the identified variables within the system. The determination of the sample size was guided by several factors. The population was established based on the registration of 600 freight forwarding companies in Egypt, as per EIFFA (2018). Consequently, a sample size with a confidence level of 95% required approximately 200 to 235 surveys (Saunders et al., 2018). Accordingly, this research involved conducting between 200 and 235 surveys.

Probability sampling was the chosen approach for this research due to its ability to facilitate data generalization for a specified population. Cluster sampling was specifically employed, considering its suitability for widely dispersed populations and its alignment with epistemological research, especially within geographical areas and zones (Acharya et al., 2013).

One-stage cluster sampling, a specific type of cluster sampling, was implemented. In this method, distinct clusters are classified, and a random sample is drawn from them (Hair et al., 2014). For instance, the chosen geographic region for data collection was Egypt, which was further divided into rural and urban areas to highlight disparities in infrastructure, road networks, and road freight transport companies in terms of size and activities. Consequently, the sample consisted of either road freight transport companies or freight forwarding companies with specialized business units in road transport activities (See Table 3.4).

While cluster sampling is relatively easy to implement and cost-effective, it has been noted by Taherdoost (2016) that interpreting results from data gathered through cluster sampling can pose challenges (Taherdoost, 2016). To address this, diverse data collection methods were employed.

Table 3.4 Cluster Sampling Procedures

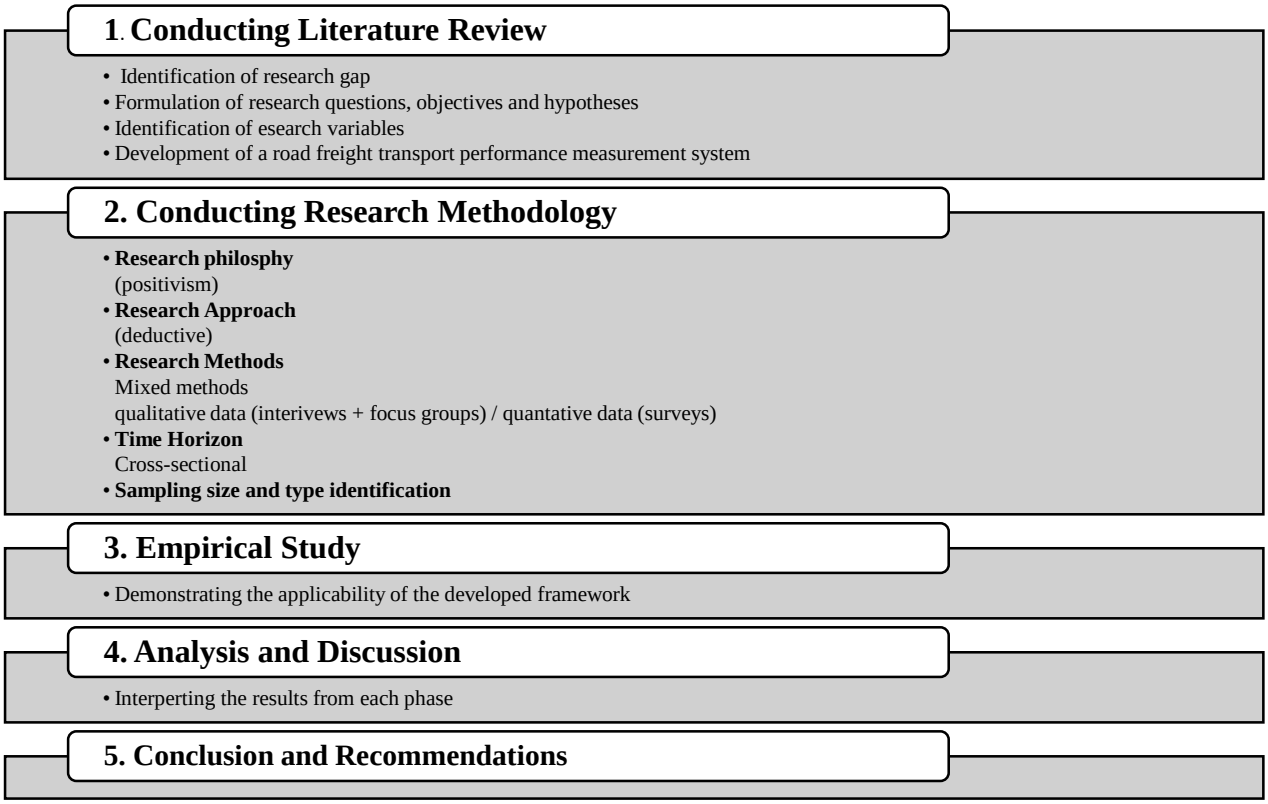
Cluster	Sample	References
Geographical area and region	Egypt (rural and urban areas)	1
Companies and sector	✓ Government road freight transport companies ✓ Private road freight transport companies ✓ Multi-national freight transport companies ✓ The Egyptian Ministry of Inland Transport	2
Participants' position	**Practitioners:** ✓ Top-tier managers and directors ✓ Operational managers ✓ Logistics managers ✓ Quality managers ✓ Business development managers ✓ Consultant engineers ✓ Accountants ✓ Clearing and forwarding executives ✓ Transport and maintenance managers **Academics:** ✓ Dean of College of International Transport & Logistics ✓ Head of Transport and Logistics Department ✓ Head of Supply Chain and Logistics Department ✓ Head of International Trade and Logistics	3
Gender	✓ Males ✓ Females	4
Educational level	✓ Bachelor's degree ✓ Master's degree ✓ Doctoral degree	5

From this table, it can be inferred that the sample chosen for this research is clustered based on region (1), companies (2), participants' positions (3), gender (4), and educational levels (5). A single-cluster stage is adopted for conducting surveys to capitalize on the advantages of this approach. Notably, cost and time reduction, enhanced sampling efficiency, and targeted region selection increase the likelihood of conducting face-to-face surveys as opposed to using mail, thereby yielding more accurate and relevant responses (Saunders et al., 2019). One primary limitation of this method is the potential inaccuracy of the collected data, as the sampling is calculated within a defined population and might not entirely represent the entire population (Alatawi, 2017). To address this limitation, the entire population was segmented into various clusters to ensure that the calculated sample size covers the entire population. Additionally, participants were chosen based on their experience and educational level in the field of transport and logistics. The selected companies were categorized into government-owned, privately-owned, and multinational road freight transport companies to ensure data collection from entities with diverse ownership, operational levels, and departments. Ultimately, diverse

research methods were employed to collect data, thereby mitigating potential limitations that may arise in each phase (Hair et al., 2014; Saunders et al., 2019).

Furthermore, focus groups were conducted to demonstrate the applicability of the developed road freight transport performance measurement system. Different criteria were established for each focus group. For instance, the number of participants ranged from 5 to 12 individuals in each focus group. The participants were carefully selected based on their strong background in the field of road freight transport, and the chosen companies varied in size, operations, and activities (Hair et al., 2014; Saunders et al., 2018). Each focus group targeted three to five companies, with 5 to 8 participants selected from each company.

The research philosophy, strategy, approach, and data collection methods for this research have been illustrated (see Figure 3.3). Additionally, the sample size and sample type have been outlined for each research phase, along with the specified criteria for conducting the focus groups.



3.3 The Research Design

3.4. Research Phases

In this section, the four research phases are comprehensively discussed. The research methods employed in each stage are elucidated, along with the tools adopted for analysing the collected data in each respective phase.

3.4.1. Research Phase 1 - Developing the Theoretical Framework extracted from the Literature Review

The first phase of this research involved the presentation of a literature review, which aimed to emphasize the significance of the road freight transport industry and the role of performance measurement in enhancing companies' sustainability-driven performance. The phase sought to analyse the main challenges encountered within the road freight transport sector and underscore the influence of technology in elevating the overall performance of the sector.

For conducting the literature review, a narrative approach was chosen. This approach involved selecting keywords, such as "road freight transport importance," "performance measurement," "sustainability," "road freight transport performance measurement system," "road freight transport problems," and "technology in road freight transport," to conduct an extensive search. A variety of sources, including journal papers, books, conference proceedings, and reports, were consulted in this process (Saunders et al., 2012).

This phase also highlighted the research gap, formulated research questions, and established a conceptual framework for road freight transport performance measurement (Creswell et al., 2019). The framework ensured the provision of clear responses to the initial research question and consequently fulfilled the primary objective (Lane, 2018). Furthermore, themes for use in the second phase of data collection were identified (see Table 3.5).

3.4.2. Research phase 2 - Developing the Conceptual Framework and investigating the current situation in the Egyptian Road Freight Transport Sector

The second research phase was dedicated to investigating the prevailing state of the road freight transport sector in Egypt, with the objective of identifying key variables to be integrated into the road freight transport performance measurement system.

In this phase, interviews were chosen as the data collection method due to their qualitative nature, which facilitates the collection of real-world insights from participants within actual industries. Interviews are acknowledged as an effective tool for addressing specific research questions (Rowley et al., 2014) and enable researchers to gather comprehensive details. Qualitative research, including focus groups and interviews, fosters conversation and

information exchange, rendering them ideal instruments for capturing primary data in the research domain (Bengtsson & Fynbo, 2018).

Rowley et al. (2014) emphasized that interviews are predominantly used in qualitative research to gather facts, summarize industry situations, and gain deep insights into opinions, experiences, processes, or predictions. Interviews can be conducted individually, and these are referred to as "individual interviews." Hence, designing interviews and selecting appropriate interviewees empowers researchers to accumulate a diverse range of pertinent and valuable data.

Distinct types of interviews exist unstructured, semi-structured, and structured interviews. The semi-structured interview stands as the most popular and flexible method, offering accessibility, comprehensibility, and the ability to reveal important facts concerning human and organizational behaviour. It represents an effective qualitative tool for gathering information, such as understanding how managers attribute meaning to their roles and environments. An important feature that sets semi-structured interviews apart is their reliance on a guide, not a rigid script (Qu et al., 2011; Kvale & Brinkmann, 2009).

The semi-structured interview entails a set of prepared questions, wherein identified themes are presented systematically and consistently. These themes are interwoven with inquiries designed to elicit comprehensive responses (Saunders et al., 2019). Thus, the semi-structured interview emphasizes an interview guide that covers broad themes, steering the conversation toward desired topics and issues (Alvesson & Deetz, 2000, p. 194).

Consequently, the semi-structured interview proves relevant in this phase of the research, as it enables the exploration of the Egyptian road freight transport sector's current status through interviews with diverse participants. Themes and codes are derived as initial steps toward validating the developed road freight transport performance measurement system. Moreover, the semi-structured interview is apt for collecting data directly from truck drivers, particularly in the social aspect of the performance measurement system. This aspect pertains to their encountered challenges during trips, encompassing working conditions, technology use, accidents, and how their performance on roads is evaluated by their respective companies.

The semi-structured interview can be conducted in a single round with one or two participants or via the Delphi method. The Delphi method involves a panel of experts providing anonymous responses in multiple rounds until consensus is achieved. This method proves beneficial for

soliciting expert opinions on specific issues or forecasting solutions (Saunders et al., 2019; Hanfer et al., 2019).

In this context, conducting semi-structured interviews using the Delphi method is deemed more relevant for this stage. The Delphi method allows for an exploration of the road freight transport sector's current state and the role of technologies in its enhancement. It also aids in identifying detrimental factors affecting sector performance. The Delphi method was incorporated in this research to gather participants' insights on road freight transport industry challenges, their perspectives on the developed performance measurement system, barriers to its implementation, and potential mitigation strategies. Widely used in transport and logistics studies, the Delphi method facilitates thorough information collection and prediction, benefiting from diverse participants' input (El-Thani et al., 2018; Freudendal-Pedersen et al., 2019; Tobey et al., 2019; Hammad et al., 2017).

The Delphi method served as a pilot stage to validate the primary problems, Key Performance Indicators (KPIs), and technological applications to be incorporated into the road freight transport performance measurement system (Eriksson et al., 2015). Survey questions were adapted based on outcomes from the Delphi rounds. Semi-structured interviews were carried out, employing the Delphi method during the first and second rounds.

3.4.2.1. The Delphi Method and Process

The Delphi method is primarily employed to structure group communication and acquire an overview of expert opinions on complex problems and uncertain outcomes. It adheres to a structured design while granting participants the flexibility to revise their responses (Bryson et al., 2016).

Participants have the opportunity to amend their answers based on received feedback or to confirm their initial responses. This iterative process, along with feedback control, can continue until specific stopping criteria are met, such as a predetermined number of rounds, participant consensus, or result stability (Van Zolingen et al., 2003). Different variants of the Delphi method exist, including classical Delphi, decision Delphi, policy Delphi, and group Delphi. The classical Delphi, adopted in this research, involves collecting responses across rounds and revising feedback until stability or consensus is achieved (Murto et al., 2019).

The Delphi method was employed as a pilot phase in this research to gather participants' insights on road freight transport challenges and the role of adopting technological applications to mitigate sector-related negative impacts. Additionally, it was utilized to assess the current state of the Egyptian road freight transport sector, achieving consensus among participants regarding key problems to be addressed, thus enhancing road freight transport companies' operational performance, and facilitating sustainability (Elgazar et al., 2023; Murto et al., 2019). This approach also explored whether road freight transport companies in Egypt measure their performance and what elements influence their performance measurement, all of which inform the developed performance measurement system (Eriksson et al., 2015).

The Delphi process encompasses various stages, including expert panel selection, question preparation, participant statement synthesis, statement grouping and categorization, statement evaluation, result analysis and interpretation, and iterative rounds. This study employs a mixed-method research design within the Delphi process, incorporating both qualitative and quantitative methods for data collection and analysis. The Delphi method is often chosen in research studies that employ methodological and data triangulation through successive mixed methods (Ghazali et al., 2019).

Typically, the first round of Delphi studies focuses on qualitative data collection through unstructured or semi-structured questions to gather detailed responses. This qualitative data richness aids in formulating focused questions or statements. In this research, the first round posed questions to road freight transport managers in Egypt. The analysis in Chapter Four reveals a high level of consensus attained for each question in the first round. The second round directed another set of questions to truck drivers, who hold a significant position in the developed road freight transport performance measurement system (Howard, 2018). The qualitative content and thematic analysis of the data from the first and second rounds serve as a foundation to adapt survey questions. This analysis uncovers categories and themes that emerge from the data.

Consensus percentages in Delphi studies are not universally predefined; they vary based on the research topic, problem, and number of participants. A planned consensus level or percentage is often set for subsequent data analysis (Ocampo et al., 2018; Mead & Moseley, 2001). While Mannix (2011) suggests a consensus level of 70 to 75%, Whitehead (2008) sets it at 80%. For Maxwell et al. (2015), a 51% consensus is deemed sufficient. Lower consensus percentages

are accepted if they remain stable across different rounds, indicating agreement among participants. The results in Chapter Four indicate high consensus percentages for questions in both the first and second rounds, ranging from 70 to 90%. Consequently, questions are not repeated across multiple rounds.

The Delphi technique is flexible and adaptable, accommodating various study scenarios. Group sizes can range from 4 to 3000 participants, with typical Delphi studies involving 20 to 50 participants (Bloem et al., 2018; Brady, 2015; Schneider et al., 2016). The Delphi method exhibits flexibility by combining quantitative and qualitative data sources. Moreover, it prioritizes participants' expertise on specific topics over the overall participant count, contrasting with sample size-based approaches (Skulmoski et al., 2007; Marsden et al., 2003; McKenna et al., 2002; Mead & Moseley, 2001).

Delphi methods serve as tools for proposing solutions, forecasting opportunities, and problem-solving across qualitative, quantitative, and mixed-method research. Panel sizes are determined based on expertise in a specific field, not population calculations. Therefore, this method typically involves 20 to 50 participants (Bloem et al., 2018). The first and second rounds of Delphi focus on qualitative data collection, as responses guide subsequent survey question adaptation. The number of Delphi rounds can range from 1 to 6 iterations, with researchers deciding when to conclude based on factors such as consensus achievement or recurring responses (Schneider et al., 2016).

Each expert's anonymity from other participants allows for candid opinions and responses. The Delphi method serves as an effective forecasting tool for planning, problem-solving, and decision-making, providing insights derived from multiple interview rounds to enhance expert insights (Dimitrijević et al., 2012). It contributes to investigating and addressing the main research question: Can the developed road freight performance measurement system enhance company performance by identifying and addressing problems and areas for improvement? The following section delves into participant selection and the quantity and type of participants needed for this research.

Determining the panel size for Delphi studies lacks standardized guidelines, leading to variation in participant sample sizes. Delphi studies involve panels ranging from 10 to over 100 participants. Notably, most transportation-related Delphi studies comprise 20 to 100 participants. Participant selection primarily focuses on the relevant field, emphasizing two key groups: top-tier managers contributing to Delphi study outcomes and professional drivers, whose input is vital for Delphi responses (Melander et al., 2019; Delbecq et al., 1975). (See Table 3.5).

The panel members encompass both academics (experts in road freight transport and performance measurement) and practitioners (participants from road freight transport companies, drivers, and customers). For instance, studies by Islam & Zunder (2013) and Dimitrijević et al. (2012) indicate the use of 100 participants for Delphi rounds in road freight transport, while other studies within European freight transport and logistics quality standards involve 100 participants in the first Delphi round, though participation of 90 remains valid (Islam & Zunder, 2013).

3.4.2.2. Advantages of using the Delphi Technique

1. The Delphi technique is an efficient tool for soliciting participants' opinions, particularly those of decision-makers, while investigating the current situation of the road freight transport sector in Egypt (Elgazar et al., 2023; Bloem et al., 2018; Brady, 2015). The validity of models and concepts predicted through the Delphi method is assessed by examining the degree of agreement among participants concerning the meaningfulness of the propositions. As a result, Delphi studies can be utilized with both positivist and interpretivist research methods (Rechberg, 2018).
2. The Delphi method serves as an effective tool for bridging previous studies conducted in a specific area, such as identifying the main challenges faced by this sector, exploring the role of technology adoption in mitigating these issues, examining the measurement of road freight transport companies' performance, and investigating the situation of truck drivers in terms of safety, advanced technology use, and the key challenges they encounter during goods transportation (Hanfer et al., 2019).
3. Comparatively, a traditional questionnaire necessitates a larger sample size than that required for the Delphi method (though a substantial population exists for road freight transport companies in Egypt, a minimum of 250 questionnaires is needed for data collection). With the Delphi technique, the emphasis on achieving a high response rate

is replaced by the assessment of consensus reached (Skulmoski et al., 2007; Marsden et al., 2003).

4. The Delphi technique not only elicits agreeing or disagreeing opinions for each question but also provides explicit explanations for participants' agreement or disagreement. Participants can review and provide comprehensive arguments as to their positions, given the anonymity of their responses (McKenna et al., 2002).
5. The iterative round until consensus is reached and the feedback revision contribute to data enrichment, as rounds are repeated until unanimous agreement is achieved from all participants—a feat not attainable through questionnaires. In this research, the Delphi technique is employed as a pilot phase for exploring the current situation of the road freight transport sector in Egypt. Two rounds are conducted to capture the requisite data, rendering the collected data more reliable and precise (Schneider et al., 2016).
6. Respondents remain anonymous to each other but not to the researcher, affording the researcher the ability to address mixed data situations—a distinction from traditional questionnaires where participants may also remain anonymous to the researcher (Mead & Moseley, 2001).
7. Participants comprehend and propose solutions to the identified key issues (Yousuf, 2007). Participants are expected to contribute insights into the principal challenges facing the sector, the role of technology adoption in mitigating these challenges, and the essential performance measurement for assessing road freight transport companies on an operational level.
8. The percentage of error tends to be higher in questionnaires compared to the Delphi technique, as the Delphi approach allows participants to amend their responses—an option not present in questionnaires (Bloem et al., 2018).
9. The Delphi method permits researchers to select participants from various backgrounds, including academia, government, public sectors, and practitioners. Consequently, researchers can engage participants from diverse spheres based on their expertise and understanding of road freight transport, sector significance, performance measurement, and sustainability. Participants are expected to possess a minimum of five years' experience in the field, whether practical or academic, as their experience and knowledge contribute to the generalizability of the developed road freight transport performance measurement system (Dimitrijević et al., 2012).

10. The Delphi method is guided by dynamics rather than statistical power in achieving participant consensus. Based on prior studies employing the Delphi technique in the same domain, a range of 12 to 100 participants is deemed sufficient (Okoli & Pawlowski, 2004), which is the sample size employed in this research.

3.4.2.3. Delphi Rounds: Results and Analysis

The Delphi method was chosen as a qualitative data-guiding tool in this research, enabling participants to elaborate on their viewpoints regarding the present situation of the Egyptian road freight transport sector. Additionally, participants had the freedom to anonymously revise their responses multiple times. By analysing and coding the data furnished by participants, categories tied to key themes were formulated. Sixty percent of these themes emerged from the analysis of first-round data, while eighty-five percent resulted from the second-round analysis. Consequently, these categories are closely associated with the identified themes (refer to Chapter Four). Subsequently, the researcher would adapt the survey questions for the upcoming phase, aiming to assess the relationships within the components of the developed performance measurement system.

Thematic and content analyses were employed to scrutinize the semi-structured interviews (qualitative data), facilitating the attainment of participant consensus for each question, along with the development of themes and categories. The NVivo software was selected as the tool for data analysis (as discussed in Chapter Four).

3.4.3. Research phase 3 - Validating the Conceptual Framework through conducting an Empirical Study in Egypt

In this phase, a structured survey was tailored and developed based on the outcomes derived from the preceding semi-structured interviews. The aim was to validate the developed road freight transport performance measurement system and corroborate the findings obtained from the first and second rounds of the Delphi method. The survey was designed to elucidate participants' perspectives on the aspects, dimensions, and performance measurements encompassed within the developed system (Mann, 2016).

Quantitative data analysis was conducted on the survey results to provide a conclusive response to the core research question: Can the developed road freight performance measurement system, which prominently features technology, enhance the performance of road freight transport companies by identifying issues and areas in need of improvement? The survey serves as an effective tool for enhancing decision-making, presenting a set of questions or metrics for

participants to respond to and record (Hair et al., 2014). Moreover, it enables the testing of relationships between identified variables (Rowley, 2014). Various techniques for framing survey questions can be employed, including open-ended questions, closed-ended questions, Likert scales, and multiple-choice questions. In this context, the most relevant approach is adopting the Likert scale, which facilitates gauging participants' opinions on specific variables (Saunders et al., 2019). Consequently, the Likert scale is employed in this study to gauge participants' opinions on the variables outlined in the developed conceptual framework.

Prior to collecting responses from all participants, the survey questions underwent a pilot-testing phase for validation. Five participants were selected for this purpose, including three practitioners with extensive experience in freight transport and two academics functioning as assistant professors in the field of logistics and transportation. Feedback from practitioners resulted in recommendations to include additional performance metrics based on their practical experiences and encountered challenges. The academic participants primarily emphasized enhancing the survey's structural clarity, suggesting modifications to present variables in a more straightforward manner to facilitate responses. Additionally, an open-ended question was proposed to afford participants the opportunity to provide supplementary insights. Integrating these recommendations from the pilot survey enriched the survey's structure, rendering it more comprehensible.

Cluster sampling was employed to determine the sample size based on the selected population for this research. The specific criteria guiding cluster sampling are elaborated upon in section 3.2 of the study.

For assessing the relationships between research variables, regression and correlation analysis were chosen, with multiple regression analysis being well-suited to gauge the degree of correlation among variables. SPSS software was employed for analysing and interpreting the survey results (Hair et al., 2014) (see Chapter Five).

To summarise, the third phase of this research aims to validate the developed road freight transport performance measurement system, establish the relationships between variables, and present the extent of correlation and interdependence among these variables. As a result, the subsequent fourth phase of the study concentrates on demonstrating the practical application of the developed road freight transport performance measurement system through the execution of focus groups within Egyptian road freight transport companies.

3.4.4. Research phase 4 - Proposing a Roadmap for adopting the Proposed Framework within the Egyptian Context

The fourth phase aimed to outline a roadmap for the adoption of the proposed framework within the Egyptian context. While interviews are an option for data collection in this stage, focus groups were chosen due to their suitability. Focus groups provide a valuable approach for discussing focused topics or issues within a group setting, making them particularly suitable for the current context. In contrast, interviews tend to gather data from one or two participants on specific topics (Sugovic et al., 2016; Saunders et al., 2019). Consequently, focus groups were utilized in this phase to engage participants in discussions about the barriers to implementing the developed performance measurement system, identifying potential solutions to these challenges, and exploring the impact of the system on road freight transport companies' performance.

Focus groups offer cost and time efficiency (Sugovic et al., 2016) and serve as effective tools for brainstorming, generating creative ideas, and refining concepts (Holloway et al., 2017).

A focus group provides an excellent platform for delving deeply into participants' perceptions, encouraging sharing, interaction, and agreement or disagreement on specific topics. This format facilitates the creation of codes and themes based on participants' viewpoints. The interviewer, acting as a moderator, guides the focus group through questions and fosters a dialogue that highlights diverse perspectives (Hair et al., 2014). The utilization of focus groups in this study allows for the collection of participants' experiences and insights regarding the application of the developed performance measurement system within road freight transport companies. This encompasses challenges, potential solutions, and recommendations for implementation (Mishra, 2016).

The number of companies required for focus groups varies according to research considerations, such as sample size calculation and research focus. In this study, three companies were deemed sufficient, with three focus groups conducted. This approach facilitated theme identification, and the selected companies were chosen to represent diverse ownership structures, sizes, and operational contexts within the Egyptian road freight transport sector (Hennink et al., 2019). Guest et al. (2016) suggest that 80% of themes arise after the first and second focus groups, with 90% emerging from the third. Consequently, three focus groups were deemed adequate for theme creation, coding, and categorization, enhancing the sector-wide generalizability.

The focus group questions underwent pilot testing with two companies to ensure their clarity and meaningfulness to participants. Incorporating suggestions for improvement arising from these pilot studies, adjustments were made, such as presenting questions individually rather than in combination. Additionally, participants recommended the inclusion of an open-ended question to allow for the addition of supplementary information (Breen, 2006).

The composition of focus groups can involve various managers from a single company or different companies within a session. The number of participants per session typically ranges from 5 to 12, with larger numbers potentially compromising the session's quality. Participant selection and group size depend on participants' experience and background related to the research topic (Jarab et al., 2018). The number of participants required for each focus group is determined based on research considerations and accessibility, generally falling within the range of 5 to 12 (Nyumba et al., 2018). In this research, five participants were selected from each company based on their field experience.

For this study, focus groups were conducted by posing a set of semi-structured questions to group managers within selected companies. The objective was to illustrate the applicability of the developed road freight transport performance measurement system. The focus groups aimed to identify expected obstacles and challenges in establishing an effective measurement system, strategies for overcoming these barriers, and insights into how the system can contribute to measuring road freight transport companies' performance. The semi-structured approach allowed participants to express viewpoints based on their practical experiences. Thematic and content analysis were employed to scrutinize focus group data, unveiling obstacles, challenges, and recommendations for successful system implementation.

The selection of participating companies was based on specific criteria to ensure representation of various features, such as size, operations, and departments. For ethical considerations, companies were anonymized as Company A, Company B, and Company C (see Appendix 2). Different selection criteria are applied for focus group sampling based on research aims, objectives, questions, and the desired outcomes (Ciesielska et al., 2018).

Various preparatory steps precede focus group sessions, including participant selection, venue determination, sending a focus group protocol to participants (see Appendix 2), assembling necessary tools (notes, recorder, pen), and choosing the appropriate data analysis method (Nyumba et al., 2018). In this context, a mini-focus group was adopted, with participants and companies chosen based on ownership and experience levels. Each focus group included five

participants, selected to provide relevant data for research aims and objectives (Ciesielska et al., 2018; Nyumba et al., 2018). Additionally, it's noteworthy that focus groups for this research were conducted during the COVID-19 pandemic, and only a limited number of participants agreed to share their insights (see Table 3.5).

The participating companies encompass a multinational organization, a private sector entity, and a governmental entity. These companies exhibit distinct sizes, operations, and departmental structures. Specifically, Company A engages in global logistics and transportation across multiple modes, while Company B conducts internal road-based logistics within Egyptian provinces and international transport via sea. Company C focuses on internal truck transportation within Egypt. The selection criteria aimed to showcase the application of the developed road freight transport performance measurement system across various companies with diverse activities, sizes, ownership models, and service qualities.

The table below provides a summary of the research phases, the employed tools, and the outcomes achieved throughout the four phases of this research.

Table 3.5 The Research Phases, Tools utilized and their Expected Outcomes.

Phases	Tools	Outcomes
Phase One: Developing a road freight transport performance measurement system Recognising the relationship between adopting technological apps and innovative practices and improving the performance of road freight transport companies	Presenting previous studies on the road freight transport sector, including examination of performance measurement, sustainability, and the role of technology in enhancing performance, as well as analysing the road freight transport industry globally and specifically in Egypt (secondary data)	Concluding the conceptual framework through the lens of sustainability, including the main dimensions and KPIs under each aspect by incorporating technology as a main aspect serving them
Phase Two: Investigating the current situation of the road freight transport sector	Utilising semi-structured interviews for collecting data from both practitioners and academics in the field of road freight transport regarding the current situation and problems facing the road freight transport sector by adopting the Delphi method	Highlighting and concluding the main variables to be incorporated in the developed road freight transport performance measurement system
Phase Three: Validating the developed road freight transport performance measurement system	Validating and confirming the results of the Delphi methods for the developed road freight transport performance measurement system by conducting surveys	Validating the developed road freight transport performance measurement system incorporating the main KPIs used in measuring the road freight transport companies' performance
Phase Four: Demonstrating the applicability of the developed road freight transport performance measurement system	Conducting focus groups in Egyptian road freight transport companies to identify the obstacles and challenges of adopting the developed road freight performance measurement system and how to overcome them	Testing the applicability of the developed road freight transport performance measurement system

3.5. Research Validity and Reliability

Content validity is employed in this study due to its association with a form of validity that ensures comprehensive and adequate measurement of various features, skills, and behaviours:

1. Triangulation: This validation method is chosen to bolster data and findings validity by gathering information from multiple sources such as surveys, interviews, and prior studies concerning road freight transport and performance measurement. Recognizing the potential insufficiency and weaknesses of relying on a single data collection technique, the integration of data from diverse sources and methodologies serves to enhance the credibility of research findings. The triangulation of both qualitative and quantitative data serves to validate the outcomes (Creswell et al., 2019).

2. Member checks: The second validation approach utilized in this research involves verifying outcomes with participants, affording them the opportunity to review and confirm the results. By providing interviewees with their interview results and interpretations, the content of their contributions can be validated, thereby reinforcing the credibility and dependability of the information (Zohrabi, 2013; Melander et al., 2019).

To ensure research reliability in this study, the following steps were undertaken:

1. Triangulation of data reliability: Achieved through the accumulation of data from diverse sources, including interviews, surveys, and focus groups. For this study, data was sourced from various outlets and participants, encompassing research and journal papers, books, practitioners, and academics in the field of road freight transport. The collection of data through multiple avenues bolsters data reliability and verifies research outcomes. This reliability is further affirmed by the execution of focus groups with Egyptian road freight transport companies, showcasing the practical implementation of the developed road freight transport performance measurement system (Creswell et al., 2017).

2. Internal reliability: This type of research reliability is pursued to ensure uniformity in data collection, analysis, and interpretation. Employing data recording as a means of internal reliability enhances consistency. All data collected is meticulously recorded and securely stored, enabling ease of re-analysis or data repetition, if necessary (Zohrabi, 2013; Saunders et al., 2019). All interview and survey questions have

undergone pilot testing, and all acquired data is thoroughly recorded and securely stored (see Appendix 4).

With the establishment of the research's validity and reliability methodologies, the subsequent section will address potential risks and limitations that may arise throughout the research process, along with strategies for mitigating them.

3.6. Research Risks and Limitations

While the chosen research methods have been thoughtfully selected, potential weaknesses must be acknowledged and addressed:

1. Semi-structured Interviews: A weakness of this approach is the possibility of limited data collection due to a small number of willing participants. Interviews can be time-consuming and costly as they involve one-on-one interactions with each participant, and responses might not always align with the research scope (Hair et al., 2014). To counter the limitation of limited data, diverse data collection methods were employed to validate the results effectively.
2. Delphi Method: Adopting the Delphi method introduces risks, such as a lack of control over agreed-upon standards for each question and challenges in generalizing Performance Measurement Systems (PMS) due to sample size (Hanfer et al., 2019). While anonymity is a strength, it can also weaken ownership of ideas (Yousuf, 2007). Triangulating data can help mitigate risks associated with the Delphi method (Hanfer et al., 2019; Yousuf, 2007).
3. Survey Phase: Risks in this phase include the potential loss of control as participants respond individually via mail, as well as a low response rate which may impact result analysis (Saunders et al., 2018). Insufficient participant accessibility and selection could compromise data accuracy (Hair et al., 2014). To mitigate risks of time-consumption and ensure the necessary data, interview, survey, and focus group protocols were established and shared with participants, outlining the research overview, data requirements, and a defined timeline (Cunliffe et al., 2018) (Refer to Appendices 1, 2, 3).
4. Focus Groups: A potential limitation of focus groups is the potential for conflict of interest, where participants' opinions may stem from unrelated personal issues rather than addressing the research objectives. The sample may not accurately represent the population, and technical issues during recording might occur (Saunders et al., 2018).

Mitigating technical problems, various recording tools were employed, and note-taking from participants aided in reducing this risk (Saunders, 2018). Careful participant selection based on their relevant experience and knowledge ensured the relevance of responses. Similarly, for participating companies, their operations, activities, and ownership were meticulously considered (Cunliffe, 2018; Hair et al., 2014).

Table 3.6 outlines the identified risks, limitations, and corresponding solutions associated with the research methodology employed in this study.

Table 3.6 Research Methods Limitations and Recommended Solutions

Number	Research Methods	Risks	Solutions
1	Semi-structured interviews	- Low participant response rate - Expansive and time-consuming - Limited data may be obtained	- Different research methods adopted for data validity. - Interview, survey, and focus group protocols sent to participants before data collection to provide them with an overview of the research topic. - Different recording tools used to make sure all data is recorded. - Identified criteria highlighted to select the relevant companies and participants needed for conducting the focus groups. - Triangulation of data
2	Delphi method	- Time-consuming (iteration of rounds) - Generalisation difficulties (sample size) - Lack of agreed standards guidance	
3	Conducting surveys	- Loss of control over participants - Low rate of collecting data - Data analysis not presenting the whole sample. - Low accessibility rate - Participants not reflecting desired information	
4	Conduction focused groups	- Conflict of interest - Personal rather than general opinions expressed. - Technical problems - Sample not representative of the targeted population	

3.7. Summary

This chapter is has presented and discussed the philosophical foundation guiding this research, namely positivism. It further delved into the chosen research strategy, which is deductive in nature, and the overarching research approach, categorised as explanatory. The comprehensive framework of data collection methods was highlighted, signifying the fusion of mixed-research methods incorporating both qualitative and quantitative data. The meticulous research design has been meticulously outlined, accompanied by elucidations on sampling size and the temporal framework within which the study operates.

The four distinct research stages, their corresponding tools, and the outcomes derived from each phase are meticulously delineated. Furthermore, the mechanisms employed for ensuring the validation of research questions and the rigorous steps taken to uphold research reliability are expounded upon. The nuances of the data collection methods embraced and executed within this study are underscored, including the development of semi-structured interviews. These interviews, in particular, serve as a conduit for elucidating the challenges encountered by road freight companies, exploring the role of technology-driven applications in enhancing their performance, and assessing the prevailing performance measurement systems employed by these companies to gauge their operational efficacy.

Moreover, a comprehensive insight is provided into the methodologies utilized for analysing the gathered data from semi-structured interviews and focus groups, which encompass content and thematic analysis. The analysis of survey data is explained, involving the application of regression and correlation techniques to discern underlying relationships.

The Delphi method, chosen for its unique attributes, is elaborately discussed, and contextualized within this research. The rationale for its selection is explicitly highlighted, emphasizing its suitability to the research objectives. Pertinent details such as the number of participants, the objectives of Delphi rounds, and the contrasting features distinguishing the Delphi method from traditional questionnaires are succinctly articulated.

Finally, potential research risks and limitations are candidly addressed, accompanied by insightful strategies for mitigating them effectively. This chapter culminates by setting the stage for the subsequent chapter, wherein the interpretation of the semi-structured interviews (comprising the 1st and 2nd rounds of the Delphi method) will be comprehensively expounded, facilitated by the utilization of the NVivo software as a robust analytical tool.

CHAPTER FOUR: ANALYSING THE ROAD FREIGHT TRANSPORT SECTOR IN EGYPT

4.1. Introduction

The chapter undertakes an examination of the present state of the Egyptian road freight transport sector through an exhaustive SWOT analysis. Moreover, it employs thematic analysis to accentuate participant responses, facilitating the creation of codes and nodes. These elements are subsequently organized into distinct themes using NVivo software. Each individual question is meticulously presented, accompanied by the corresponding outcomes deduced from the responses, along with the percentage of consensus for each question.

4.2. Road Freight Transport in Egypt

Various countries are considering the substitution of road transport for the movement of freight and passengers with railways or inland waterways due to the negative impacts imposed by road transport. However, this approach is still limited in its application in Egypt due to the country's restricted inland opportunities for such substitutions (Elgazar et al., 2023; Elshahaway et al., 2017).

Egypt offers limited transportation alternatives for supply chains, with railways and inland waterways failing to provide attractive substitutes for roads. In 2018, roads accounted for approximately 92.58% of all transportation within the country, a trend that remained consistent until the end of the projected period in 2022. This heavy reliance on road networks by companies is evident (Hassan, 2018). The Egyptian Road network plays a critical role in internal freight transport services within the country (Egypt Freight Transport & Shipping Report, 2018).

Egypt's road network encompasses around 120,000 km and primarily targets Cairo and the surrounding cities due to their high population density along the Nile, Mediterranean, and seacoasts (Egypt Freight Transport & Shipping Report, 2017). The government is actively working on expanding road connections throughout the country in the medium to long term. Major road projects are planned to extend from ports such as Alexandria and Port Said to Cairo, and further south along the Nile to Asyut, Luxor, and Aswan (Egypt Freight Transport & Shipping Report, 2020). Moreover, the country's road infrastructure is being bolstered by significant investments in existing

road and highway development within and around Egyptian cities. Multiple bridges, highways, and speedways are under construction to connect various regions within the country to key strategic points (Egypt Freight Transport & Shipping Report, 2017).

The General Authority for Roads, Bridges, and Land Transport (GARBLT) in Egypt is overseeing numerous multi-billion EGP projects currently under construction across the nation. Additionally, GARBLT aims to secure a separate budget allocation in the upcoming fiscal year to further enhance the country's road transportation infrastructure (Egypt Freight Transport & Shipping Report, 2018; Elshahaway et al., 2016).

Egypt enjoys the advantage of being internationally connected through road networks linking it with neighbouring MENA (Middle East and North Africa) countries and a few SSA (Sub-Saharan African) nations. For instance, Cairo serves as a focal point for two Trans-African highways—one traverses the North African coast to Senegal's Dakar, while the other extends southward through Khartoum, Addis Ababa, Nairobi, Dodoma, Lusaka, Gaborone, and finally to Cape Town (Egypt Provision Risk Report, 2018) (see Figure 4.1).

Recent government investments in Egypt have significantly improved internal road transportation infrastructure. Outdated roads have been maintained to accommodate higher vehicle capacity, and new bridges and highways have been constructed to facilitate smoother intercity travel and reduce travel time (Egypt Freight Transport & Shipping Report, 2017; Egypt Freight Transport & Shipping Report, 2020). However, additional investments and funding are needed to cover both internal and international infrastructure maintenance (Elshahaway et al., 2016).

Currently, reliance on secondary main roads is restricted due to the lack of a sustainable land road link between Egypt and Sudan. As a result, trucks are transported to Sudan via ferry across Lake Nasser from Aswan, as heavy trucks cannot viably cross. This limitation severely hampers inter-regional trade flows. Furthermore, road connections from Egypt to Libya remain underdeveloped and require significant improvement (Egypt Freight Transport & Shipping Report, 2018).

Two primary roads connect Egypt to areas spanning the north and south of the Red Sea, either through the south of the Gaza Strip or along the coast of the Gulf of Aqaba. Another crucial road link exists between Egypt and Libya, although the ongoing instability in Libya currently impedes its proper utilisation. These insufficient road connections, along with regional security and safety concerns, limit trade volumes between Egypt and its neighbouring countries (Egypt Logistics Risk Report, 2020) (see Figure 4.1).

Egypt serves as an empirical study to validate the proposed road freight transport performance measurement framework for this research due to several reasons:

- Substantial investments are still required for infrastructure maintenance (Elshahaway et al., 2016).
- Sustainable land road links are lacking between Egypt and certain neighbouring countries (Egypt Logistics Risk Report, 2020).
- Inadequate road connections and regional security and safety issues persist between Egypt and its neighbours (Egypt Freight Transport & Shipping Report, 2018).
- Various obstacles hinder effective international road links, including acts of terrorism and the absence of signed international road conventions (Egypt Freight Transport & Shipping Report, 2020) (see Figure 4.1).

Figure 4.1 The Egyptian Road Network along the River Nile and its Main Links
Source: (d-maps.com, BMI, 2018)

The subsequent section aims to present the current state of the Egyptian road freight transport sector, with the objective of identifying the primary barriers that this sector encounters in Egypt.

4.2.1. The Current Situation of the Egyptian Road Freight Transport Sector

Over 26% of accidents occurring in Egypt every year are attributed to road transport accidents, which represent a significant and perilous concern (World Health Organization, 2015; Elshamly et al., 2017; Elgazar et al., 2023). The UN Economic and Social Council (2009) has highlighted the expansion of freight and passenger transport consumption, leading to an increase in traffic accidents on Egyptian roads.

Challenges within the road freight transport sector include rising petroleum product costs due to inconsistent consumption and occasional fuel shortages (Elgazar et al., 2023).

Moreover, many African economies, reliant on oil products for industrial and domestic use, are witnessing an escalating demand for transportation fuel, contributing to substantial human, social, environmental, and economic costs. Porter (2014) underscored a series of fuel tanker truck accidents resulting in injuries and fatalities. To mitigate such incidents, the adoption of innovative information and communication systems has been proposed as a means to improve road freight transport performance (Federal Road Safety Corps, 2015; Elgazar et al., 2023; WHO, 2015).

Hassan (2019) emphasizes that road infrastructures, particularly in African countries like Egypt, play a dominant role in both freight and passenger transportation. However, sustaining road infrastructure requires substantial maintenance efforts. Several African nations, including Egypt, Nigeria, and Ethiopia, face challenges in achieving road transport infrastructure sustainability due to inadequate funding, lax enforcement of regulations, and a shortage of skilled personnel (Egypt Freight Transport Shipping and Port; Shipping Report, 2018). Notably, about 90% of Egypt's roads are paved, yet their quality suffers from high temperatures, long distances, and limited development incentives, resulting in delays for supply chains in remote areas (Nosseir, 2016). This issue is mirrored in the World Economic Forum's Global Competitiveness Report, ranking Egypt 75th out of 140 countries in terms of road infrastructure quality (Elgazar et al., 2023; Egypt Freight Transport Shipping and Port; Shipping Report, 2018).

As attention shifts toward the road transport sector in Egypt, the government has initiated measures to promote sustainability, including setting new regulations, encouraging investment in road maintenance, and managing the sector more effectively (Egypt Freight Transport & Shipping Report, 2019; Hassan, 2019). Additionally, the burgeoning population's demand for goods has impacted the road freight market, with the overall road network length influencing trucking capacities (Elgazar et al., 2023; Egypt Freight Transport Shipping and Port; Shipping Report, 2018).

Poor infrastructures result in limited mobility, increased operational costs, and higher accident rates (Elshahaway et al., 2017). Despite Egypt's road investments accounting for 0.15% of GDP, lower than figures for Ecuador, Morocco, and Ukraine, the limited

investment poses challenges for road infrastructure maintenance (Hassan, 2019). Collaboration between the government, public sector, and private sector is essential to mitigate the negative externalities associated with road transport and achieve sustainability (Egypt Freight Transport Shipping and Port; Shipping Report, 2018).

Inadequate regulations and a lack of effective management systems also hinder the performance of road freight transport companies in some African countries, including Egypt and Nigeria (Faajir et al., 2016; De Bod et al., 2016). Notably, drivers' fatigue is a significant obstacle to sustainability within Egypt's road freight transport sector, directly impacting driver safety due to long working hours, fatigue, and impaired driving (De Bod et al., 2016). This issue contributes to higher accident rates, with 96% of road accidents attributed to drivers' attitudes (Faajir et al., 2016).

Furthermore, the road transport sector in Egypt lags in adopting Information and Communication Technologies (ICT), Intelligent Transport Systems (ITSS), and innovative solutions due to high costs, inadequate infrastructure, and a scarcity of qualified drivers (Elgazar et al., 2023; El-Husseiny et al., 2017). Additionally, a lack of rules enforcement and unified management systems for road freight transport companies further compound the challenges in the sector. Developing and implementing a road transport performance measurement system is seen as a potential solution to enhance management and performance tracking for road freight transport companies, thereby elevating the entire sector (Elgazar et al., 2023).

4.2.2. The SWOT Analysis of Road Freight Transport in Egypt

In this section, a SWOT analysis of the road freight transport sector is presented. The strengths within the Egyptian road freight transport sector are identified, along with its primary weaknesses. Additionally, opportunities and threats are highlighted.

1. **Strengths**

To date, the majority of road transport infrastructures and highways in Egypt have been well-paved, and the government is actively seeking to invest in the maintenance and enhancement of these road transport infrastructures and highways (Egypt's Provision Risk Report, 2018).

Previous studies conducted on the road freight transport sector in Egypt have highlighted the limited availability of inland transport modes to substitute road transport for moving freight and passengers (Zaki et al., 2019; El-Husseiny et al., 2017). Consequently, there is a strong imperative for the government to prioritize and significantly invest in upgrading and maintaining the road transport sector, given that a substantial portion of both freight and passengers rely on roads for transportation (Nosseir, 2016).

Increasingly, the adoption of technological apps and innovative solutions is being recognized as a crucial tool for improving the performance of road freight transport companies in Egypt, ultimately enhancing the overall performance of the sector. As a result, the government is actively working to enhance road infrastructure and highways to facilitate the implementation of technological apps such as GPS and tracking systems (Egypt Logistics Risk Report, 2020).

2. Weaknesses

One of the main problems facing the road freight transport sector is the scarcity of professional truck drivers. If they are well-trained in transporting different types of cargo, they will be better equipped to cope with new technological apps and innovative vehicles (Zaki et al., 2019; El-Husseiny et al., 2017).

The second weakness is the shortage of fuel, leading to fluctuations in fuel prices and increased journey costs (Elgazar et al., 2023; Egypt's Provision Risk Report, 2018). Traffic congestion is another critical issue, especially during rush hours, as it reduces vehicle performance, increases fuel consumption, and hampers acceleration rates (Nosseir, 2016).

Failure to adopt technological apps results from poor infrastructure, and addressing this requires greater investments and ongoing funding for maintenance (Egypt Logistics Risk Report, 2020).

According to Egypt's Provision Risk Report (2018), road accidents lead to an estimated 2.8 deaths per 100,000 people. Consequently, traffic accidents pose a high risk to freight transport. In Egypt, driving and working conditions for truck drivers need further development and improvement. Additionally, there is a lack of enforcement of road

freight transport rules and regulations. Moreover, the adoption of recent technologies such as eco-driving systems is absent due to the need for higher investments in traffic management, an insufficient supply of mass transit systems, and additional hazards arising from unmarked surfaces, uncontrolled vehicles, poor lighting, and severe weather conditions. All these factors contribute to a chaotic and perilous road driving environment.

On the other hand, traffic congestion has increased in Egypt, causing 31% of journey delays. This can be attributed to a lack of traffic management. Furthermore, 19% of journey delays result from the unreliability of journey times in recent years (Zaki et al., 2019). This implies that the increase in population size has led to insufficient implementation of Intelligent Transportation Systems (ITS) and Global Positioning System (GPS) systems, along with poor road infrastructure (Abdel Wahed Ahmed et al., 2020). Also, Egypt is notorious for truck back-door exploitation, which extends trip times without sufficient available parking areas (El-Husseiny et al., 2017; Nosseir, 2016).

3. Opportunities

New international projects are planned for implementation to connect Egypt with its neighbouring countries. For instance, the new bridge between Egypt and Saudi Arabia is expected to bolster trade and economic growth, promote tourism, and reduce travel time between the two countries (Nosseir, 2016).

Egypt's strategic location enables it to establish connections with neighbouring nations such as Sudan, Libya, and the Gulf region through new international road projects (Egypt's Provision Risk Report, 2018). Some road freight transport companies in Egypt have begun focusing on adopting technological systems, such as eco-driving and tracking systems. Consequently, these companies are willing to provide training sessions for truck drivers (Elgazar et al., 2023; Zaki et al., 2019; El-Husseiny et al., 2017).

As previously mentioned, the road freight transport sector in Egypt is undergoing significant changes and facing considerable challenges. However, several measures are proposed to enhance and improve this sector, as outlined below:

1. A plan is in place to construct a new bridge connecting Egypt and Saudi Arabia. This initiative is set to benefit the Egyptian road and rail freight sectors by facilitating trade and tourism between the two countries. The project aims to reduce travel time, enhance road infrastructure, and increase accessibility and reliability (MOT, 2017). This undertaking holds a vital role in boosting the economies of both nations and facilitating international trade through efficient road connections. Additionally, it contributes to the tourism sectors of Egypt's Red Sea cities and religious tourism in Saudi Arabia (Egypt Freight Transport & Shipping Report, 2020).
2. China is actively considering investment in Egypt through the One Belt, One Road initiative (OBOR), which aims to connect over 70 countries and prioritize infrastructure development (Egypt Freight Transport & Shipping Report, 2017). Anwar (2020) elaborated on the potential impact of OBOR on participating countries' economies, highlighting increased trade and resource allocation leading to economic growth. However, this initiative may pose environmental challenges, particularly related to air quality. It is worth noting that the OBOR project seeks to enhance and facilitate trade among a vast network of countries, fostering economic growth, improved accessibility for cargo, reasonable pricing, and larger quantities of goods (Egypt Freight Transport & Shipping Report, 2020).
3. Recent improvements in Egyptian infrastructure have notably enhanced the movement of dry bulk cargo between Egyptian ports and various countries.

In summary, Egypt boasts an extensive international road network connecting it with various nations. However, challenges such as inadequate sustainable infrastructure, insufficient investment in technological applications, lack of enforcement of international road conventions, and a shortage of professional drivers constrain its capacity for international road freight transport. Consequently, the Egyptian Government should revamp and develop the strategy for managing this sector, as its growth is pivotal for overall economic development (Egypt Freight Transport & Shipping Report, 2018).

1. Threats

One of the primary challenges facing the road freight transport sector in Egypt is the high and continually increasing accident rates (El-Husseiny et al., 2017). Unforeseen events and crises, such as the emergence of COVID-19 in 2020, can have a negative impact on all economies (Egypt Logistics Risk Report, 2020).

Another issue is Egypt's lack of membership in international road conventions, such as the TIER convention, as well as the insufficient enforcement of rules and regulations (Egypt Freight Transport & Shipping Report, 2017).

The government should prioritize the maintenance of road infrastructure, training for truck drivers, law enforcement in the management of this sector in Egypt, and pursuit of membership in road transport conventions to ensure smoother international cargo transportation and increased safety levels (Elgazar et al., 2023; Egypt's Provision Risk Report, 2018). Failure to adopt technological apps for vehicle management and tracking during freight transport results in decreased safety levels and an increase in incidents of corruption and accidents (Zaki et al., 2019; El-Husseiny et al., 2017). Other concerns include complaints about fuel shortages leading to roadblocks. Furthermore, ongoing inconsistencies in regional and domestic roads create hazardous driving conditions, particularly in specific times and areas, such as the Sinai Area and rural regions within the southern and western areas due to acts of terrorism. Therefore, investors could contribute to enhancing security and managing road freight transport travel times to reduce unnecessary costs and delays (Egypt Logistics Risk Report, 2020). Acts of terrorism pose a threat to trade in Egypt, particularly in road transport. For instance, transporting goods via trucks in North Sinai is severely limited due to terrorism (Nosseir, 2016).

The following table highlights and analyses the strengths, weaknesses, opportunities, and threats (SWOT analysis) pertaining to the current position of road freight transport in Egypt.

Table 4.1 SWOT Analysis for the Current Situation of the Road Freight Transport Sector in Egypt

Strengths	**Weaknesses**
• Well-paved infrastructures • Road transport dominance on the transport of cargo and passengers • Potentiality for incorporating technological apps	• Professional driver scarcity • Fuel shortage • Congestion problems • Poor infrastructure leading to a lack in adopting technological apps and innovative solutions for traffic management
Opportunities	**Threats**
• New projects to be implemented to link Egypt with more neighbouring countries. • The geographical location of Egypt • The willingness of some road freight transport companies to adopt technological apps	• An increase in the number of accidents • Unsigned international conventions, such as the TIER Convention and lack of enforcement of international conventions for regulating the road freight transport sector. • The occurrence of crisis • The lack of adoption of technological apps, such as ITS and ICT systems, in management and operations • Terrorist acts

Source: Own illustration

In this segment, an evaluation of the present state of the road freight transport industry in Egypt has been conducted using a SWOT analysis. The subsequent segment delves into a comprehensive examination of the existing conditions within the Egyptian road freight transport sector, accomplished through semi-structured interviews involving experts and stakeholders. We outline the criteria for selecting participants for these interviews and indicate their number, while also presenting the formulation of interview questions and the anticipated outcomes for each.

4.3 In-depth Analysis for the Egyptian Road Freight Transport Sector: Delphi Method

In this section, the Delphi method is employed to conduct a thorough analysis of the present state of the Egyptian road freight transport sector, focusing on its problems, obstacles, and challenges. This analysis is carried out through semi-structured interviews involving experts and stakeholders within this sector. The section begins by outlining the participant selection process and the number of experts chosen. It then proceeds to present the interview questions and the anticipated outcomes for each of these questions.

4.3.1. Participant Selection and Size

Semi-structured interviews were chosen as the preferred method to gather in-depth data from participants concerning the primary challenges faced by the road freight transport sector and the influence of technology adoption on enhancing the performance of road freight transport companies. This interview approach offers a comprehensive perspective on the current state of Egypt's road freight transport sector. Given that interviews effectively reflect participants' viewpoints related to the research field and objectives, the criteria for participants in the 1st and 2nd rounds of the Delphi method were initially established. The interviewees were categorized into two groups: company managers and truck drivers. By employing the Delphi technique, consensus among participants aids in the development and correlation of themes, categories, and codes (refer to Table 4.2).

The interview questions were designed to capture participants' perspectives on the newly developed road freight transport performance measurement system. The first series of semi-structured interviews involved top managers, operational managers, quality managers, logistics and transport managers, as well as financial managers from various road freight transport companies. The second series was conducted with professional truck drivers (refer to Table 4.2). Participants were chosen based on their years of experience, backgrounds, and knowledge in road freight transport, performance measurement, and sustainability. These selections aimed to gather insightful viewpoints on the primary challenges faced by their respective companies, their perceptions of technology's role in addressing these challenges, and the performance measurement systems employed by their organizations to evaluate process performance.

An alternate set of questions was developed specifically for truck drivers. These questions covered issues such as specific challenges faced by drivers, strategies for handling accidents, required training hours, methods of performance evaluation, and approaches to adapting to new systems. Consequently, this chapter presents an analysis of the semi-structured interview findings.

Forty participants, encompassing both managers and truck drivers with several years of experience in road freight transport companies (ranging from 6 to 15 years), were selected. The participant group also included managers from the Egyptian Ministry of Inland Transport. All participants were sent an invitation letter to engage in this research. Ethical considerations were thoroughly addressed, ensuring participant anonymity and safeguarding data exclusively for research purposes (refer to Appendix 1: Delphi Invitation Letter). Responses from interviewees were subjected to thematic and content analyses, involving the extraction of identified codes, creation of nodes, and the identification of overarching themes using NVivo software for qualitative data analysis (refer to Chapter Three).

Table 4.2 Research Participants Titles and their Number

Participant's Title	**Number of Participant's Involved in the 1st Round**
Road freight transport company top-tier manager (private and governmental sector)	3
Quality Manager in road freight transport company	1
Manager in the Egyptian In-land Transport Ministry	2
Supply Chain Manager in road freight transport company	1
Owner of road freight transport company	2
Operations Manager in road freight transport company	1
Technology and Innovation Department manager in Road freight transport company	1
Professional truck driver	10
Total	**21**

Forty participants were available for conducting interviews in the first and second rounds; however, only 21 interviewees (yielding a 52.5% response rate) agreed to participate. This number of respondents is considered suitable for qualitative research, as it has been recommended that a sample size of 6 to 12 interviews can provide substantial and coherent responses to research questions and objectives (Baker et al., 2012). Additionally, in qualitative data analysis, the sample size is determined by the concept of information power rather than the sheer number of participants (Malterud et al., 2015). Consequently, a smaller sample size is deemed appropriate for achieving the interview's intended purpose.

4.3.2. 1st Round Questions Design

The design of the interview questions varies according to the participants' backgrounds and experiences. The series of questions outlined in Table 4.3 was formulated specifically for managers within road freight transport companies.

Table 4.3 The 1st Group of Interview Questions Design and Desired Outputs

Interview Questions	Desired Outputs
Q1: 'Based on previous conducted studies, it was observed that congestion, infrastructure maintenance and driver qualifications are the main dimensions affecting the road freight transport through the lens of sustainability (economic, environmental and social)'. To what extent do you agree with this statement? Are there any further dimensions that should be added under each aspect of sustainability? Why?	-To sum up the main problems facing road freight transport from different aspects of sustainability as these problems stand against enhancing the performance of road freight transport companies. -To extract a summary of the current situation of the Egyptian road freight transport sector.
Q2: "Technological aids are good tools for diminishing these problems". To what extent do you agree with this statement? Why?	-To highlight the importance of adopting technological apps and innovative solutions in mitigating road freight transport problems and enhancing company performance.
Q3: How do road freight transport companies measure their performance?	-To define the existing performance measurement used by road freight transport companies in measuring their processes.

This set of interview questions in table 4.4. was designed to target truck drivers and achieve the respective outcomes as set out below.

Table 4.4 The 2nd Group of Interview Questions and the Desired Outputs

Interview's Questions	Desired Outputs
Q1: How long have you been working as a professional truck driver?	-To understand the experience of the truck driver.
Q2: 'The driver has to complete a certain type of training according to the type of freight he is responsible for transporting'. To what extent to do you agree with this statement? Why?	-To extract responses considering the required training sessions for truck drivers.
Q3: From your point of view, do you deliver the required safety level while driving the truck?	-To obtain information on the level of safety provided to truck drivers while transporting cargo.
Q4: How would you deal with a traffic accident?	-To learn about the different courses of action available to truck drivers in the instance of a traffic accident.
Q5: What external factors increase your stress level? (Prompts such as weather, congestion etc. can be provided if no answer is given)	-To focus on the main areas of stress facing truck drivers and how they affect their performance.
Q6: Does your company apply the safety regulation rules and the maximum working hours?	-To verifying the working conditions offered by road freight transport companies to their truck drivers.
Q7: How often are you subjected to drug and alcohol tests? (Once a year, a month, etc.)	-To collect the average number of random substance checks conducted by road freight transport companies.
Q8: Are you well-trained on all the new technology adopted in freight trucks and digital signs?	-To focusing on how truck drivers deal with new technological apps.
Q9: Do you wish to provide me with further information?	-To check if the interviewees wish to add any further points that might affect the research topic.

4.4. Thematic Analysis

Thematic analysis is utilized in this study to uncover themes and codes relevant to the examination of the status of Egypt's road freight transport sector. Thematic analysis is widely endorsed within transportation research due to its ability to yield precise, valuable, and comprehensive findings. It involves a systematic approach to analysing data, which enhances data reliability and validity (Nikitas et al., 2019).

Naliu et al. (2020) outlined the six key steps in conducting a thematic analysis as follows:

a. Becoming Familiar with the Collected Data

b. Generating Initial Codes

c. Identifying Emerging Themes

d. Reviewing and Refining the Identified Themes

e. Defining the Finalized Themes

f. Reporting the Obtained Results

a. Being Familiar with the Data Collected

The 21 interviews conducted with road freight transport managers and drivers were recorded, manually transcribed, and subsequently analysed using NVivo software. NVivo is a widely utilized platform for qualitative analysis, facilitating the extraction of a high-frequency word table, word clouds, and tree mapping.

b. Generating Initial Codes

With the aid of NVivo software, all gathered data were imported and subjected to analysis. Preliminary codes were identified through tree mapping, a process that encapsulates the most frequently recurring terms found within the interview transcripts. Notable words such as road, freight, transport, problems, infrastructure, drivers, performance, measurement, technology, and congestion were identified and treated as nodes. These words were aggregated based on their similarity and connection to form distinct categories. These related categories were then organized into five overarching themes.

c. Searching for the Themes

In this phase, the researcher identifies the themes aligned with the research objectives and questions. These outcomes are substantiated and illustrated by analysing and emphasizing the collected data using NVivo software, employing methods such as word clouds or tree mapping. In the context of this study, the prominently utilized terms among the chosen participants include road, freight, transport, congestion, drivers, performance, measurement, and problems.

d. Reviewing the Themes

The analysis below sets out a pool of the words frequently used based on the interviewee responses, (see table 4.5):

Table 4.5 Review of High-Frequency Words

High-frequency words	Authors	Interviews' code
Congestion	Taylor, 2008; Rodrigues et al., 2010; Boussier et al., 2011; Khanal, 2012; Demir et al., 2015; Grote et al. 2016	Interview (10) Interview (9) Interview (13)
Infrastructure maintenance	Ruli, 2016; Figliozzi, 2011; Meng& Liu, 2012; Kok et al., 2012	Interview (1) Interview (12) Interview (7)
Drivers – Stressful	Litman et al., 2006; Randall, Defee& Brady, 2008; FMCSA, 2011; Cantor, Corsi & Grimm, 2009; Kemp et al., 2013; Kuiken et al., 2001; Mayhew, 2007; Beanland et al., 2012	Interview (2) Interview (21) Interview (20)
Technology	Keeling & Mooney, 2011; Naganathan & Chong, 2017; Li and Yu, 2017	Interview (17) Interview (3) Interview (5)
Qualifications	Sultana et al., 2012; Hesse et al., 2004	Interview (14) Interview (18) Interview (11)
Profit	Lopez et al., 2008; Schoenmaker et al., 2016	Interview (15) Interview (4) Interview (8)
Sustainability (economic, environmental, and social)	Linxue et al., 2015; Bruijn 2007; Tang et al., 2015	Interview (16) Interview (6) Interview (19)

Hence, through the analysis of the collected data and a comparative examination with prior research findings, it becomes evident that the prominently recurring high-frequency words should serve as the fundamental elements for establishing and interlinking themes and categories. Furthermore, these identified themes align with the primary research questions and objectives, as they encompass the key challenges in road freight transport and recognize the role of technology adoption in addressing these issues and advancing sustainability.

Consequently, the forthcoming sections delve into a review of the identified themes, followed by the extraction of themes using the word query method based on the nodes and codes established within NVivo software. Subsequently, codes are extracted and

grouped under relevant themes. The frequency and length of each word mentioned in the interviews are presented. The main themes derived from the interview discussions include technology, sustainability, road freight transport problems, and road freight transport system and performance measurement.

e. Defining the Themes

The Nvivo software analysis of the interview transcripts reveals a range of codes and nodes, including technology adoption, lack of rules and regulations, sustainability, and performance measurement. Notably, sixty percent of the themes emerged from the 1st round, encompassing congestion, driver qualifications, infrastructure maintenance, technology, profit, and sustainability. Conversely, eighty-five percent of the themes arose from the 2nd round, highlighting technology, driver qualifications, and stress. Some themes, such as technology and driver qualifications, were reiterated in both rounds.

In light of this, four principal themes have been established, each encompassing relevant categories and codes. Every theme is assigned a code and reference based on its frequency of occurrence within the interview transcripts. For further clarification, Table 4.6 presents the themes, corresponding categories, codes, and corresponding references.

Table 4.6 An Overview of the Developed Themes

Themes	Categories	Codes	References
Benefits of adopting technologies in road freight transport sector (T)	Adoption of technological apps and innovative solutions	1	25
	Mitigation of the road freight transport problems		30
	Enhancement of the road freight transport performance		15
Sustainable road freight aspects and dimensions(S)	Economic Aspect (congestion problems and infrastructures maintenance)	2	25
	Social Aspect (Driver qualifications and training)		20
	Environmental Aspect (congestion problem and infrastructure maintenance)		30
Road Freight Problem (RP)	Key problems: infrastructure maintenance, congestion problem and scarcity of professional drivers	3	40
	Barriers: the lack of adoption of technological apps and lack of enforcement of rules and regulations		19
Measuring road freight transport companies' performance (PM)	The measurement of working hours, driver fatigue, speed limits, stress and pressure, compliance with traffic rules, use of illegal drugs, land use impact, noise and air pollution, public health, traffic jam, car exhaust rate, accessibility, reliability. trip delay, factory delay, mobility, operations cost, productivity improvement, fuel cost, safety, fuel consumption, driver's trainings, severe weather, sleepiness, rush hours, gas emissions, accident rates, trip delay	4	45
	The assessment of the road freight transport performance to measure companies' performance and investigate decisions for enhancing performance		30

It is observed that road freight transport problems and the road freight transport performance measurement have the highest word frequencies. Then, the adoption of technology and its benefits are followed by sustainable aspects and dimensions.

f. Reporting the Results

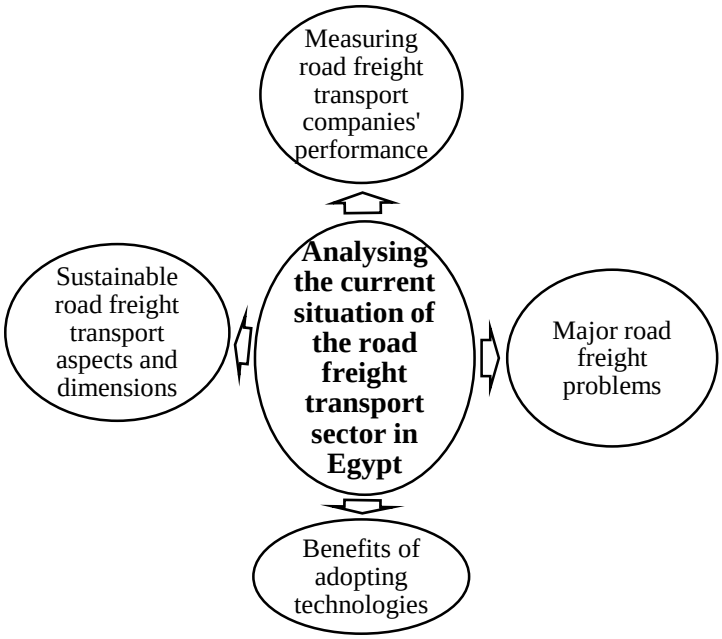


Figure 4.2 Themes Identified

The purpose of the thematic analysis was to categorize codes into distinct categories and subsequently formulate overarching themes based on participant responses. The primary themes that emerged encompassed the advantages of integrating technologies into the road freight transport sector (code 1), the dimensions and facets of sustainable road freight transport (code 2), significant road freight challenges (code 3), and the role of performance measurement within road freight transport companies, involving the identification of a set of performance metrics (code 4). The analysis of the interviews, coupled with the delineation of themes, categories, and codes, highlights a positive correlation between performance measurement, the adoption of technological applications, innovative solutions, problem mitigation within road freight transport, and the pursuit of enhanced sustainability.

Each theme comprises several categories. Firstly, the adoption of technologies is envisioned to ameliorate road freight transport issues, contingent on the enforcement of effective rules and regulations governing the sector. Furthermore, the pertinent codes associated with these categories are elaborated upon.

The second established theme identifies three principal aspects as categories: economic, environmental, and social. Within each category, road freight challenges are underscored in accordance with their impact across these sustainable dimensions.

The third theme delineates key road freight challenges and obstacles, validating these codes as the central problems confronting the sector and impeding its operational performance.

The fourth theme is bifurcated into two pivotal categories: firstly, Key Performance Indicators (KPIs) employed for evaluating companies' performance, and secondly, the role of assessment and issue identification in informing decisions aimed at augmentation.

Indeed, the interrelationships among the various variables explored within this study have been discerned, aligning with the purpose of adopting the Delphi method. This approach has facilitated a comprehensive examination of the present state of the road freight transport sector, coupled with an exploration of the necessary stages for its enhancement (see Figure 4.2).

Code 1: Benefits of adopting Technologies in the Road Freight Transport Sector

The inaugural theme established is "Benefits of Adopting Technologies in the Road Freight Transport Sector" (T), as it emerged recurrently in various interviewee responses. This theme encompasses three distinct codes, namely adoption, mitigation, and enhancement, which are situated within the technology framework. These codes and corresponding categories are integrated under theme (T), as depicted in Table 4.5.

The interviewees underscored the potential substantial influence of mobile applications on streamlining operations within the road freight transport industry. Such applications could encompass functions like truck booking, administrative tasks, packaging and handling specifications, and freight rate calculations. Furthermore, the interviewees emphasized the advantages of integrating tracing systems, which would enable companies to monitor trucks during their journeys, facilitating prompt intervention by drivers in case of issues and acting as a preventive measure against cargo thefts.

A road freight transport companies top manager said: *"I totally agree with the impact of technology on lessening the aforementioned problems as technological aids should assist in improving quality, but it increases the trips' cost"…….P1,* while a Quality Manager in one of the road freight transport companies states: *"I totally agree with the impact of technology on enhancing the performance of road freight transport companies as it facilitates the management of trips and drivers and avoids congestion areas. Moreover, it aids in increasing trip quality and reliability and in reducing trip delays …" P4.*

A quote from one of the drivers: *"I am trained on using some of the technology apps, but not all, adopted by the company I work in, such as GPS and tracing systems. As for digital signs, they are all well-known to all drivers and they cannot renew their licenses without being tested about them" ……D7.*

To that point, it is evident that the adoption of technologies within this sector will yield a significant and direct impact on alleviating the challenges encountered by road freight transport companies. Consequently, this will lead to an enhancement in trip quality and safety. In light of this, the initial category within the theme of technology benefits is defined in accordance with the insights gathered from the interviewees – namely, the adoption of technologies within the road freight transport sector.

An Operations Manager in one of the road freight transport companies stated that "…*Newly innovative trucks are needed to replace the obsolete ones, which impacts the environment, driver's safety and maintenance cost as the aforementioned problems have direct environmental, economic and social impacts. Accordingly, technology apps should assist in reducing their impacts by designing journey routes to be able to estimate trip duration and delays, for instance*…" *P10.*

While another driver mentioned, *"I am trained to work on some of the technology apps, not all, adopted in the company I work with, such as GPS and tracing systems, eco-driving applications, journey planning applications and digital signs." D5*

In this context, the adoption of technologies is expected to exert a positive influence on this sector, aiding in the alleviation of road freight transport issues. As a result, the second category formulated within this theme pertains to D5.e mitigation of road freight transport problems.

Code 2: Sustainable Road Freight Transport Aspects and Dimensions

The second theme established is "Sustainable Road Freight Transport Aspects and Dimensions" (S), which has been subdivided into three distinct categories. The initial category, "Economic Aspect," is discerned through the compilation of codes associated with the "congestion problem and infrastructure maintenance." These elements impact the economic aspects of road freight transport companies. The subsequent category, "Social Aspect," incorporates the code "driver training and qualifications," which directly influences the performance of road freight transport companies from a social standpoint. The third category, "Environmental Aspect," encompasses the codes "congestion problem and infrastructure maintenance," both of which bear adverse environmental consequences for road freight transport companies. The codes and corresponding categories constituting the "Sustainability" theme are delineated in Table 4.5.

A total of eleven interviewees emphasized the necessity of implementing driver training programs, as they equip drivers with the tools to effectively navigate the diverse challenges encountered on the road. However, it is regrettably noted that not all companies provide their drivers with adequate training. On this topic, one e driver said,

"*Totally agree … but not all road freight companies provide training sessions. However, to renew our license, certain courses and tests have to be provided. In my company, there are a lot of training sessions on how to use technological apps, how to deal with accidents occurrence and how to control hazardous cargoes while transporting them …" D3.*

Another driver said, "Training is a must, not an option for professional drivers. Companies, which are looking forward to enhancing and improving their operations, offer various types of training for their drivers as they are key to the companies' enhancement. I definitely agree with the above statement." D5.

Another driver stated that problems include *"delay because of congestion, port procedures, severe weather, working conditions and sleepiness due to the absence of predefined working hours in Egypt, fatigue and feeling unsafe on the road"* D7.

In summary, road freight transport problems exhibit diverse adverse effects from a sustainability standpoint. For instance, issues such as congestion and infrastructure maintenance exert influences on both the economic and environmental facets of the sector. Conversely, driver training and qualifications directly impact the sector socially. Consequently, the second theme, "Sustainability in the Road Freight Transport Sector," encompasses these three dimensions – economic, environmental, and social – and encapsulates the associated problems according to their specific impacts.

Code 3: Major Road Freight Problem

The third established theme is "Major Road Freight Problem" (RP), which encompasses two designated categories. The first category is "Key Problems," formed by aggregating the codes "congestion problem, infrastructure maintenance, and the scarcity of professional drivers." The second category, "Barriers," incorporates the codes "lack of enforcement of rules and regulations for the road freight transport sector and the lack of adoption of technological apps and innovative solutions." These codes and categories are situated within the overarching theme of "Road Freight Problem," as depicted in Table 4.5.

Participants initially highlight a critical issue: the lack of comprehensive training and education among drivers. This shortfall renders some drivers ill-equipped to navigate new technological advancements within road freight transport companies. Despite certain companies' endeavours to enhance driver performance through various training sessions encompassing safety, problem-solving, and technology utilization, the efforts to enhance driver safety remain somewhat constrained. For example, the manager in the Egyptian In-land Transport Ministry lists the main problems facing the Egyptian road freight transport industry in Egypt by stating that there is a *"limitation of transporting goods via road internationally due to a conflict of interest between countries in managing the road freight transport sector" P1.*

The owner of one of the road freight transport companies stated that "*there are various problems facing the road freight transport sector, such as congestion problems resulting from the allowance period for the movement of trucks in Egypt"- P3.*

A road freight transport company manager in the Technology & Innovation Department confirmed *there was an "absence of adopting technology in enhancing the road freight transport performance." They went on to add that, "Truck drivers need more training to be well qualified to deal with different types of cargo. Furthermore, no specific working hours' conditions are applied in Egypt. For example, the drivers are working per trip, not per specified working conditions, as is the case in other countries. Consequently, they may experience sleepiness on long trips, get exposed to substance/drug abuse in order to be able to complete the trip, or have their cargo stolen if they take a nap." P2.*

The efficiency of the road freight transport sector has diminished since the events of the 2011 Revolution. Neighbouring countries have curtailed cargo volumes exported from and imported into Egypt. The tonnage of transported goods has dwindled, and certain nations have ceased trade with Egypt altogether. Consequently, a number of road freight transport companies in Egypt have ceased operations, unable to sustain profitability.

Truck drivers in Egypt require extensive training to heighten their awareness of the perils of driving under the influence of drugs. However, the substantial costs of such training are beyond the means of many companies. In this context, collaboration

between the government and road freight transport companies is imperative to make these crucial training sessions accessible at affordable rates.

Another participant elucidated the predominant issues afflicting the Egyptian road freight transport industry. They underscored drivers' inadequate education and the absence of a comprehensive training system for international regulations and protocols. The absence of established working hours for drivers due to lax law enforcement contributes to a surge in drug and substance abuse incidents. Furthermore, the high rate of driver turnover is attributed to the pursuit of higher incomes.

The second significant challenge in the road freight transport sector is market fragmentation. Competitiveness is predominantly gauged based on cost, while factors such as trip quality, encompassing reliability, trip duration, and cargo delivery standard, are often overlooked. Most road freight transport companies lack performance measurement systems and fail to adopt technological tools and innovative solutions, including GPS, journey planning apps, and eco-driving. Their focus remains solely on cost competition. Additionally, the lack of regulatory enforcement in the road freight transport sector in Egypt adversely affects both company performance and the environment. Fluctuations in fuel costs, truck maintenance, and extended trip durations amplify environmental impact through heightened gas emissions and increased fuel expenses.

One participant stated, "*There are no specific working hours' conditions applied in Egypt. For example, the drivers are working per trip, not per specified working conditions as is the case in other countries* …" *P6.* Another one said: "… *there are no predefined working hours* …" *P5.* A further example is *"...technology is not adopted for enhancing the road freight transport performance ..." P7.* Two interviewees mentioned that revolutions and instabilities impact the road freight transport sector negatively, *as "the performance of the road freight transport sector nowadays is not quite as efficient as before the 2011 Revolution because some of the neighbouring countries have reduced the amount of cargo exported from Egypt and the amount of cargo imported to Egypt" P10. "Consequently, some road freight transport companies in Egypt have shut down their businesses as they were unable to run their business or gain profit". P4.*

Concerning infrastructure maintenance, only the road freight transport company manager of the Technology and Innovation Department witnessed some sort of progress in the infrastructure of road transport in Egypt. For example, he said: *"… not all truck drivers are well-trained to deal with the various types of cargoes transported via road or to deal with the risks they may face while transporting cargo from origin to final destinations, especially when transporting cargo internationally between two different countries. Also, if there is any type of technology adopted, not all drivers can cope with using it as they prefer to use the ordinary/common type of trucks …" P11.*

An additional barrier identified for the sector is that there are no predefined working hours; it is calculated by trip. However, if the trip is long, there are rest stops that drivers should follow. For safety, some companies monitor their speed and GPS. One of the drivers stated: *"The working hours are not limited, it is per trip, but in case of long trips, there are rest stops I have to follow. Safety is monitored by the company through restricted speed limits, the GPS, and a tracing system. Danger may arise during the trip due to external factors such as poor infrastructure, bad weather and cargo theft" D4.*

Another driver discussed working hours by stating *"working hours in my company per trip are not predefined. Also, I should have a minimum number of trips per month. For my safety, the company provides me with a certain suit that I should wear while transporting goods, especially hazardous materials. In addition, the speed limits are not exceeded, and the rest stops are followed in case of long trips*." *D10.*

a. Measuring Road Freight Transport Companies' Performance (code 4)

The fourth theme, denoted as "Measuring Road Freight Transport Companies' Performance" (PM), encompasses two distinct categories. The initial category is "Measurement," derived from the compilation of codes encompassing a range of factors such as "Working hours, Driver fatigue, Speed limits, Stress and pressure, Compliance with traffic rules, Use of illegal drugs, Land use impact, Noise and air pollution, Public health, Traffic jams, Car exhaust rate, Accessibility, Reliability, Trip delay, Factory delay, Mobility, Operations cost, Productivity improvement, Fuel cost, Safety, Fuel consumption, Driver training, Severe weather, Sleepiness, Rush hours, Gas emissions, Poor truck lashing, Accident rate, and Trip delay."

The second category is labelled "Assessment," wherein the codes "identifying the road freight transport performance, measuring companies' performance, and investigating decisions for enhancing performance" are presented. These codes and corresponding categories are situated within the overarching theme of "Performance Measurement," as outlined in Table 4.4.

Interviewees detailed specific indicators employed by their respective companies for performance evaluation. These include measures like energy consumption (utilizing GPS mileage data, acceleration rate, and truck mechanical condition assessment), rush hour management, trip delay assessment, trip duration (via GPS and journey trip), and eco-driving evaluation (analysing speed and acceleration) to gauge driver performance. Furthermore, measures such as random drug and alcohol testing, implementation of safety protocols, panic buttons for immediate assistance, journey planning with tracking software, and tracking checkpoints to manage trips are used to enhance safety, reliability, and minimise delays. Some companies employ the count of trips executed as an indicator of overall company performance. Others use financial reports as an indicator, as one interviewee said *"…unfortunately, we don't apply any systems for measuring our performance. However, we measure our performance based on the end of the financial year whether the company earned profits or not …" …. P5.* While another interviewee explained that his company has its own performance measurement whereby *"…there is a selection criterion for drivers and a certain number of trainings that have to be conducted" P3.*

Some participants suggested that the Ministry of Inland Transport in Egypt should enforce rules and regulations to manage the road freight transport sector and identify a general criterion for road freight transport companies to follow. There was some indication that technological aids are highly recommended, as one interviewee stated: *"… restructuring the Technological Department in the Ministry of Transport can serve the sector and enhance its performance" P6.* On the other hand, the performance of drivers is usually measured by target achievements, the number of accidents and crashes rates or the number of trips. For example, one driver stated: *"… the number of accidents and crash rates are estimated to identify the performance of drivers on roads and the trucks' performance …" P8.*

Another interviewer added to this, and stated, *"In my point of view, the safety degree is not stable as there are internal and external factors standing against the safety of the driver on the road; internal factors such as the lack of training, exceeding speed limits, sleepiness and truck obsolesce, whereas external factors are weather conditions, poor infrastructure, lack of service on roads and congestion." D6.*

Most truck drivers in Egypt do not work for a predefined number of working hours. This can affect their stress level and anxiety as they may be tired or want to sleep. Consequently, they may not be able to concentrate on their journeys and they feel unsafe.

One respondent stated, "*There are different factors, from my point of view: driver fatigue, sleepiness, the working conditions, port procedures, congestion, poor infrastructure and weather conditions." . D8.*

4.5. First and Second Round Results Analysis (Delphi Technique)

This section presents an analysis of the interview questions and the level of participants' agreement (utilising the Delphi method) for each question. Transcripts are employed to identify the earlier established themes. The interview questions are divided into two groups, with each group transcribed individually to showcase the interviewees' consensus for each question autonomously.

During the initial round, the majority of participants reached agreement on the responses to each question, as delineated in the ensuing sections. Consequently, the questions from the first round were not reiterated in the second round. The Delphi technique was chosen as a pilot phase to achieve consensus concerning the challenges confronting this sector and the role of technology adoption in performance measurement and the mitigation of adverse effects. This initiative aims to offer future decision-makers assistance in attaining sustainability goals. Subsequently, the survey questions were restructured based on participants' feedback from both rounds.

A thematic analysis was adopted to assess the degree of agreement among participants' responses in the first and second rounds, utilizing NVivo software to identify and formulate themes and categories. Attaining a reasonable level of consensus is intended

to facilitate the identification of primary problems significantly impacting the road freight transport sector. This process guides the redesign of survey questions, encompassing essential performance measurements for diverse road freight transport companies at an operational level. Furthermore, this exploration delves into the role and benefits of technology to aid managers in devising decisions and strategies for enhanced sustainability.

The ensuing section delves into the analysis of interviewees' responses for each question, elucidating the extent of agreement for individual questions and ultimately concluding the sought-after outcomes of the interviews. The interview responses undergo thorough analysis through thematic analysis, carried out over two distinct rounds. The first round is dedicated to analysing managers' responses, while the second focuses on the input provided by drivers.

4.5.1. The 1st Round Interview's Responses Analysis

This set of interviews encompassed a diverse range of participants, including managers from road freight transport companies, managers from the Egyptian Ministry of Transport, former owners of road freight transport companies, quality managers from private road freight transportation companies in Egypt, operational managers from private road freight transportation companies in Egypt, managers from the Quality and Technology Department in a road freight transport company, top-tier managers of Inland Transport in the Egyptian Ministry of Transport, and top-tier managers of governmental road freight transportation companies in Egypt (refer to Table 4.2).

These interviews were conducted with the objective of gathering comprehensive insights into the present and prospective state of the global road freight transport industry, with particular emphasis on Egypt. The purpose was to gather information encompassing the prevailing barriers encountered by the road freight transport sector. Furthermore, the inquiry extended to the exploration of existing performance measurement systems employed by companies to evaluate their performance. Additionally, the study investigated the role of adopting technological applications and innovative solutions in mitigating these challenges and enhancing the operational performance of road freight transport companies.

The questions were structured as follows:

1. Question 1 - “Based on previous studies, its congestion, infrastructure maintenance and driver qualifications are the main dimensions affecting road freight transport through the lens of sustainability (economic, environmental and social)’. Do you agree with this statement? Are there any further dimensions that should be added under each aspect of sustainability? Why?”

The majority of the interviewees concurred in response to the aforementioned points. Congestion, infrastructure maintenance, and driver scarcity are recognized as the primary challenges confronting road freight transport companies, given that these issues exert a direct adverse influence on the road freight transport sector across various environmental, social, and economic dimensions. Interviewees highlighted that drivers contribute to some of the challenges faced by the road freight transport sector, owing to factors such as fatigue during extended journeys, and the limited availability of professional, well-trained, and educated truck drivers with sufficient experience to handle the demanding nature of the job. Additionally, many drivers lack the necessary reflexes to respond effectively to sudden accidents and problems.

Furthermore, participants affirmed that congestion exerts a direct negative impact across diverse sustainable dimensions and indirectly affects driver performance. Similarly, infrastructure maintenance has wide-ranging sustainable consequences, directly affecting the operational performance of both trucks and drivers. The responses to this question are presented within the themes of "Sustainability Aspects and Dimensions" (S) and "Major Road Freight Problem" (RFP) (refer to Table 4.7). **Table 4.7 Participants’ Responses to 1st Question**

Interview question	Number in agreement	Number in disagreement	Total	Percentage of agreement
Q1: ‘Based on previous studies, congestion, infrastructure maintenance and driver qualifications are the main dimensions affecting the road freight transport through the lens of sustainability (economic, environmental and social)’. Do you agree with this statement? Are there any further dimensions that should be added under each aspect of sustainability? Why?	10 participants agreed	1 participant disagreed. (Operations Manager in a road freight transport company). The participant felt that the infrastructure in Egypt was showing great development. Therefore, from the participant’s point of view, infrastructure maintenance was not a main problem.	11	90.9%

2. Question 2 - "Would technological aids be good tools for diminishing these problems?"

Interviewees proposed that truck drivers in Egypt require additional training programs and sessions to effectively handle various types of cargoes transported by road, enhance their understanding of sustainability practices, and steer clear of substance abuse. Unanimously, all interviewees concurred that technological tools have the potential to alleviate the challenges faced by the road freight transport sector. This consensus led to the emergence of the first theme, namely the "Benefits of Adopting Technologies in the Road Freight Transport Sector" (T) (refer to Table 4.8).

Table 4.8 Participants' Responses Rate to 2nd Question

Interview question	Number in agreement	Number in disagreement	Total	Percentage of agreement
Q2: Technological aids are good tools for diminishing these problems. Do you agree with this statement? Why?	11 participants agree	-	11	100%

3. Q*uestion* 3 - "How does a road freight transport company measure its performance?"

The theme "Measuring Road Freight Transport Companies' Performance" (PM) was established, reflecting the consensus among the majority of interviewees who acknowledged the absence of a dedicated performance measurement system within most road freight transport companies (refer to Table 4.9).

Table 4.9 Participants' Responses Rate to 3rd Question

Interview question	No. of performance measurement adopted	Adoption of performance measurement	Total	Percentage of agreement
Q3: How does a road freight transport company measure its performance?	8 participants' companies do not adopt performance measurement systems for measuring their performance.	3 participants' companies adopted performance measurement systems for measuring their performance.	11	72.7%

In conclusion, across the three questions, interviewees demonstrated agreement ranging from 70% to 100% regarding the primary challenges afflicting the road freight transport sector both globally and in Egypt. These challenges encompass congestion, road

infrastructure maintenance, the scarcity of proficient truck drivers, and the deficiency of effective regulatory frameworks governing the road freight transport industry, particularly in countries like Egypt.

Furthermore, unanimous consensus is evident among all interviewees regarding the pivotal role of technology adoption in enhancing and mitigating the impact of the issues confronting road freight transport companies, thereby contributing to the pursuit of sustainability.

Among the 10 managers interviewed, who represent a spectrum of entities including the Egyptian Ministry of Transport and various road companies differing in size, operations, and scope, there is a shared acknowledgment of the prevalent absence of comprehensive performance measurement systems within most Egyptian road freight transport companies. Consequently, many of these companies rely on rudimentary tools for gauging their performance, such as year-end profits, trip counts, GPS utilization, and sporadic driver evaluations.

Some interviewees posit that the road freight transport sector in Egypt suffered adverse repercussions following the events of the 2011 Revolution. Several road freight transport businesses were forced to shutter, while others have faced significantly diminished profitability since that time. The government's formulation of regulatory guidelines for overseeing the road freight transport sector should factor in these challenges. The subsequent section provides an analysis of interviews conducted with truck drivers.

4.5.2. The 2nd Round Interviews' Responses Analysis

The second set of interviews involved truck drivers. These interviews employed a distinct set of questions tailored to gather insights based on their first and experience in the field.

1. Question 1 - "How long have you been working as a professional truck driver?"

The majority of the drivers have 5 to 15 years of experience, with some having worked as truck drivers for 5, 7, 8, 13, and 15 years. Only two drivers had more extensive experience, with one having worked as a professional truck driver for 20 years and another for 25 years.

2. Question 2 - “the driver has to complete a certain type of training according to the type of freight he is responsible for transporting’. Do you agree with this statement? Why?”

All the interviewees universally agree that training is essential for their job as it assists them in enhancing their driving skills and knowledge. Firms usually invest in their employees to boost their productivity, save money, and increase profit in the long term (see table 4.10). Accordingly, the theme arising is "sustainable road freight transport aspects and dimensions" (S).

Table 4.10 Drivers’ Responses Rate to 2nd Question

Interview question	Number in agreement	Number in disagreement	Total	Percentage of agreement
Q2: ‘The driver has to complete a certain type of training according to the type of freight he is responsible for transporting’. Do you agree with this statement? Why?	10 participants agree	-	10	100%

3. Question 3 - “From your point of view, do you deliver the safety required while driving the truck?”

Generally, most interviewees believe that there are various challenges during their journey and that these affect their safety on routes negatively. Challenges such as severe weather, poor road infrastructure and congestion were cited. These are mapped as a category linked to the theme "measuring road freight transport companies’ performance" (PM) (see table 4.11).

Table 4.11 Drivers’ Responses Rate to 3rd Question

Interview question	Same opinion rate	Different opinion rate	Total	Percentage of agreement
Q3: From your point of view, do you deliver the safety required while driving the truck?	8 drivers have produced the same answer. They deliver the safety level needed while driving.	2 drivers have different responses. They need more precautions and safety on roads.	10	80%

4. Question 4 - "In the instance of accidents, how do you deal with these?"

The majority of responses (9 participants) state that they stop driving immediately and contact their company. One participant stated, *"In case of accidents, I stop the truck totally, deal with the company to provide me with all the aids, procedures and tools to follow*." D1.

Another driver states: *"In case of accidents, there are two options: either to stop the truck totally and contact the company or to try to reach the nearest service provider on the road."* D10.

5. Question 5 - "What external factors increase your stress level?

For this question, an example should be provided by the interviewer only if participants do not understand the question. For instance, examples like weather or congestion can be given.

All of the interviewees mentioned the same factors that could affect their stress levels, such as congestion, adverse weather conditions, and the absence of necessary procedures for transporting cargo from one point to another.

6. Question 6 - "Does your company apply the safety regulation rules and the maximum number of working hours or not?"

The interviewees mentioned that their companies do not have a predefined number of working hours (see table 4.12). Working hours are determined by the trip, and as a result, there are no maximum limits on working hours. This question highlights the fact that the lack of enforcement of rules and regulations is one of the main problems facing the sector.

Table 4.12 Drivers' Responses Rate to 6th Question

Interview question	Number in agreement	Number in disagreement	Total	Percentage of agreement
Q6: Does your company apply the safety regulation rules and the maximum number of working hours?	All participants agree that there is no predefined number of working hours adopted by their companies.	-	10	100%

7. Question 7 “How often are you subjected to drug and alcohol tests? (Once a year, a month, etc.)”.

All the interviewees agree that random drug checks are conducted on a regular basis and are not pre-warned. The frequency of these checks varies from one company to another. While the minimum number mentioned is three, some companies perform up to six or eight random checks.

One participant said: *“Drug and alcohol tests are done randomly and are not pre-announced, and the random tests are made at least 6 times per year.” D1.*

Another driver states that *“the drug and alcohol tests are done randomly and are not pre-announced, but the least number of random tests made are from 3 to 6 times per year” D4.*

8. Question 8 - “Are you well trained on all the new technology adopted in freight trucks and digital signs?”

All the interviewees agreed that they are not trained on all the new technologies launched to serve the road freight transport sector. However, they receive training on the technologies adopted by their respective companies. It's worth noting that they need to be familiar with all digital signs, as their driving licenses cannot be renewed without passing a government-administered test on the usage and interpretation of digital signs. This question aligns with the theme "Benefits of Adopting Technologies in the Road Freight Transport Sector" (T).

9. Question 9 - “Do you wish to provide me with any further information?”

The respondents seemed to focus on the fact that more thoughtfulness is needed to be given to drivers as the driver’s job is not easy and is highly stressful in the current situation in Egypt. One interviewee said that *“the driver’s job is very stressful, and more care is needed for the drivers to increase their safety, reduce crash rates, improve their working conditions and change the culture of truck drivers in Egypt” D4.*

Another driver stated: *“Road freight transport rules and regulations should be launched in Egypt to protect the interest of the road freight transport companies, drivers and customers, and obsolete trucks should be replaced with new ones.” D2.*

In summary, interviewees unanimously agreed that continuous training sessions for truck drivers are essential to equip them with the skills to handle the challenges they encounter and elevate their professionalism. Additionally, measures should be taken to enhance their safety while transporting cargo on roads. It was further emphasized that the government should establish standardized working hours, set a maximum limit, and improve working conditions through training sessions and awareness campaigns to address unforeseen situations, reduce accident rates, and enhance driver performance. Furthermore, all interviewees acknowledged the stress and numerous challenges inherent in their job, underscoring the need for greater care and appreciation in this field.

4.6. Summary

The aim of the interviews was to highlight the current situation of the road freight transport sector in Egypt, the challenges facing road freight transport companies and the role of adopting technology in enhancing the performance of both the road freight transport companies and the truck drivers as well. The NVivo software was utilised to analyse the interviews to extract the most frequently used words via word frequency clouds and tree-mapping. These words are presented according to the nodes created: performance measurement, sustainability, road freight transport problems, technology adoption and the road freight transport system. Consequently, these words were categorised based on similarity, and then tailored under the identified themes. Moreover, a thematic analysis is conducted for the two groups of interviews, the answers for each question presented manually, and the repeated comments highlighted to highlight the majority agreement of the interviewees for each question.

CHAPTER FIVE: AN EMPIRICAL STUDY ON THE EGYPTIAN ROAD FREIGHT TRANSPORT CONTEXT

5.1. Introduction

This chapter aims to empirically test the proposed road freight transport performance measurement framework within the context of Egyptian road freight transport. A survey was conducted to assess the research hypotheses and identify the most relevant measurements for the proposed framework. Subsequently, a roadmap for implementing the framework in the Egyptian road freight transport context was developed based on focus groups with local transport companies. The outcomes of the survey and focus groups will address the 4th and 5th research questions, thereby fulfilling the 3rd and 4th research objectives.

The structure of the chapter is as follows: Section 5.2 presents the survey design, followed by a depiction of the descriptive analysis in Section 5.3 and the normality testing of the survey results in Section 5.4. The regression analysis of the proposed road freight transport performance measurement framework is outlined in Section 5.5, followed by a discussion of the relationships between the research variables and the hypotheses' results in Section 5.6.

Section 5.7 provides insights into the focus group conducted to propose the roadmap for implementing the proposed framework. The focus group design and the analysis of results using NVivo software are detailed. Finally, Section 5.8 summarizes the entire chapter.

5.2. Testing the Developed Road Freight Transport Performance Measurement framework

A survey was conducted during the 3rd research phase to assess the effectiveness of the proposed road freight transport performance measurement framework. Regression analysis was performed to examine the relationships between the variables within the proposed framework and to determine the degree of correlation among these variables. As a result, the subsequent section initially delves into the formulation of the survey questions and subsequently presents the outcomes concerning the validation and reliability assessment of the variables.

5.2.1. Survey Design

The survey questions were crafted in alignment with the proposed road freight transport performance measurement framework derived from the literature review. The formulation of these questions underwent a redesign, considering the insights and themes drawn from the analysis of semi-structured interviews. The primary objective of the survey was to examine the interrelationships among variables within the proposed road freight transport performance measurement framework. Consequently, the survey primarily centres on elucidating the components it encompasses (refer to Appendix 3).

Comprising five main sections, the survey begins with demographic inquiries in its initial section, encompassing factors such as age, experience, and educational background. Subsequently, the ensuing three sections concentrate on distinct dimensions of sustainability and the role played by technological applications. Within these sections, the primary issues identified under each dimension are presented, incorporating the performance metrics intended for gauging the influence of these issues on the operational performance of road freight transport companies. The fifth section features an open-ended question, affording participants the opportunity to contribute any supplementary information that could aid in the refinement of the performance measurement system.

Participants were categorized based on their respective backgrounds: practitioners engaged in the freight forwarding sector or within the Ministry of Inland Transport, along with academics specializing in the domains of logistics and transportation management, specifically focusing on operations and performance measurement. The target group encompassed two hundred participants, determined through population-based calculations, with corresponding invitation letters dispatched (see Appendix 3). A noteworthy ninety-five percent of the participants responded to the survey. Consequently, the forthcoming section details the survey findings, employing SPSS for the analysis of results and validation of relationships between the established variables for performance measurement. This analysis encompasses descriptive assessments of research variables and respondent profiles, accompanied by normality testing for research variables. The research hypotheses are subjected to scrutiny through correlation and regression tests. The utilization of SPSS is pivotal for comprehensively

analysing the conducted surveys, thereby fulfilling the research's overarching objectives.

5.2.2 Validity and Reliability Tests

For the assessment of validity and reliability, Cronbach's alpha was employed to measure reliability, and it was observed that all research variables and observations surpassed the predefined threshold for internal consistency, with all items scoring 0.8 or higher (Sonmez et al., 2020). Consequently, the obtained results are deemed reliable. Additionally, AVE (Average Variance Extracted), KMO (Kaiser-Meyer-Olkin), and Factor Loading analyses were conducted after the removal of statements with inadequate Factor Loading values (below 0.4) to test reliability. The eliminated statements pertained to economic aspects (reliability, mobility, car crashes, operating cost, productivity improvement, safety), social elements (drivers' crash rates, driving training, use of controlled substances and alcohol), and environmental factors (noise and air pollution, public health). Given that this research embraces reflective validity, it necessitates the removal of statements with unfavourable factor loading values (Nikniaz et al., 2017). Consequently, the data employed in this study are considered valid after the exclusion of statements with inadequate factor loading values.

To ascertain the reliability and validity of the survey questions, along with exploring relationships between diverse variables and assessing their correlations, content, construct, and convergent validities were employed. Content validity was achieved by encompassing all facets of the construct that this research seeks to evaluate. Within construct validity, two forms exist (formative and reflective) (Storkholm et al., 2018). Reflective construct was chosen for this research due to its focus on devising a performance measurement framework from a sustainable perspective, integrating the three facets. To probe the influence of implementing the developed performance measurement system and to examine relationships between variables through regression analysis (Khan et al., 2016), it was determined that all average variances extracted exceeded 50%, and factor loading surpassed 0.4 (after eliminating select items with factor loading values below 0.4). Consequently, this data is considered valid. Convergent validity was ensured through the utilization of two distinct tools for measuring relationships between varying variables. Upon validation, Cronbach's alpha values surpassed 0.8, indicating an acceptable level of reliability for the coefficient values of the variables. Furthermore, KMO values (Kaiser-Meyer-Olkin) exceeded 0.6,

signifying sufficient sampling adequacy and rendering further actions unnecessary (refer to Table 5.1).

Table 5.1 Validity and Reliability Testing

Variables	KMO	AVE%	Cronbach`s Alpha	Items	Factors loading
Economic Aspect	0.811	64.704	0.904	Item 1	Deleted
				Item 2	Deleted
				Item 3	Deleted
				Item 4	Deleted
				Item 5	Deleted
				Item 6	0.457
				Item 7	0.775
				Item 8	0.681
				Item 9	0.757
				Item 10	Deleted
				Item 11	0.594
				Item 12	0.772
				Item 13	0.494
Social Aspect	0.727	64.876	0.859	Item 1	0.613
				Item 2	Deleted
				Item 3	0.665
				Item 4	Deleted
				Item 5	Deleted
				Item 6	0.557
				Item 7	Deleted
				Item 8	0.752
				Item 9	0.657
				Item 10	Deleted
Environmental Aspect	0.807	57.262	0.862	Item 1	0.493
				Item 2	0.482
				Item 3	0.725
				Item 4	0.462
				Item 5	0.645
				Item 6	0.659
				Item 7	0.543
				Item 8	Deleted
				Item 9	Deleted
Technology	0.694	68.615	0.845	Item 1	0.508
				Item 2	0.602
				Item 3	0.818
				Item 4	0.816

5.3. Descriptive Analysis

Descriptive statistics serve as a tool to delve into the characteristics of a given dataset, providing concise summaries of samples and methods for quantifying the data (Hair, 2015; 2011). The three primary categories of descriptive analysis encompass frequency-based measurements, which gauge occurrences, measurements of central tendency such as means, and evaluations of variability, including standard deviation. Measurement of variability elucidates the extent of divergence of scores from the mean, while measurement of central tendency proposes a singular value that generally encapsulates the overall set of scores.

Frequency statistics tally the occurrences of each variable. In the subsequent section, means, standard deviations, and frequency statistics are outlined for both demographic data and research variables. Table 5.2 presents the respondent profile. It is evident that the number of male respondents surpasses that of female respondents, constituting 71.1%, whereas female respondents account for 28.4%. Furthermore, the highest count of respondents possesses bachelor's degrees, representing 77.9% of the sample.

Table 5.2 Respondent Profile

	Frequency	**Percent**	**Total no. of participants**
Gender			
Male	68	71.6	95
Female	27	28.4	
Educational Level			
Bachelor's Degree	74	77.9	95
Master's Degree	4	4.2	
Doctoral Degree	17	17.9	

Table 5.3 displays the means and standard deviations for the research variables. Notably, the mean values for the research variables are as follows: telecommunications and intelligent applications (1.0211), cargo owner application (1.0316), driver applications (1.0105), economic sustainability (0.9579), social sustainability (1.0737), and environmental sustainability (0.9789). A standard deviation of less than 1 suggests that the data tends to be in proximity to the mean.

Table 5.3 Descriptive Analysis for the Research Variables

	N	Mean	Std. Deviation	Frequency		
				1(disagree)	2(agree)	3(maybe)
Telecommunications and intelligent applications	95	1.0211	.02985	3	87	5
Cargo Owners Applications	95	1.0316	.03158	3	86	6
Driver's Applications	95	1.0105	.02798	3	88	4
Economic Sustainability	95	.9579	.02071	4	91	0
Social Sustainability	95	1.0737	0.02695	94	1	0
Environmental Sustainability	95	.9789	.02985	5	87	3

5.4. Normality Testing for the Research Variables

In accordance with the formal tests for normality, which assess the equality of mean, mode, and median of variables through tests such as Kolmogorov-Smirnov and Shapiro-Wilk, as indicated in Table 5.4, the obtained p-values are less than 0.01. These outcomes stem from the predominant consensus among participants. Consequently, it is discerned that these variables do not exhibit a normal distribution. In light of this formal test, the null hypothesis can be rejected, specifically:

H0: The variable follows a normal distribution.

Ultimately, the initial hypothesis that can be affirmed is articulated as follows:

H1: The variables do not conform to a normal distribution.

Table 5.4 Formal Testing of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Telecommunications and Intelligent Applications	.476	95	.000	.383	95	.000
Cargo Owner Applications	.478	95	.000	.408	95	.000
Driver Applications	.473	95	.000	.355	95	.000
Economic Sustainability	.540	95	.000	.202	95	.000
Social Sustainability	.537	95	.000	.286	95	.000
Environmental Sustainability	.476	95	.000	.383	95	.000

Skewness and kurtosis, employed for assessing normality through descriptive analysis, exhibit values that fall within the acceptable range of 2 and -2. While some scholars propose a broader acceptable range of 3 to -3, others advocate for a more stringent range between 1 and -1, especially when a precise adherence to normal distribution is crucial (Garson, 2016). In the context of this study, the analysed variables display a near-normal distribution, as depicted in Figures 5.1, 5.2, and 5.3. Based on this finding, the hypotheses support the application of parametric tests. Considering the variables are approximately deviating from a normal distribution, the Spearman correlation emerges as an appropriate method for gauging the relationships between research variables, as illustrated in Table 5.5.

Table 5.5 Informal Testing of Normality

	Skewness		**Kurtosis**	
	Statistic	**Std. Error**	**Statistic**	**Std. Error**
Telecommunications and Intelligent Applications	0.660	0.247	9.326	0.490
Cargo Owner Applications	0.803	0.247	7.862	0.490
Driver Applications	0.418	0.247	11.182	0.490
Economic Sustainability	-4.634	0.247	19.888	0.490
Social Sustainability	3.316	0.247	9.190	0.490
Environmental Sustainability	-0.660	0.247	9.326	0.490

Figures 5.1, 5.2, and 5.3 display the Normal Q-Q plots for the economic, social, and environmental aspects, corresponding to the findings in Table 5.5. It is evident that the data do not conform to the alignment with the reference line. Consequently, it can be inferred that the data lacks a normal distribution pattern.

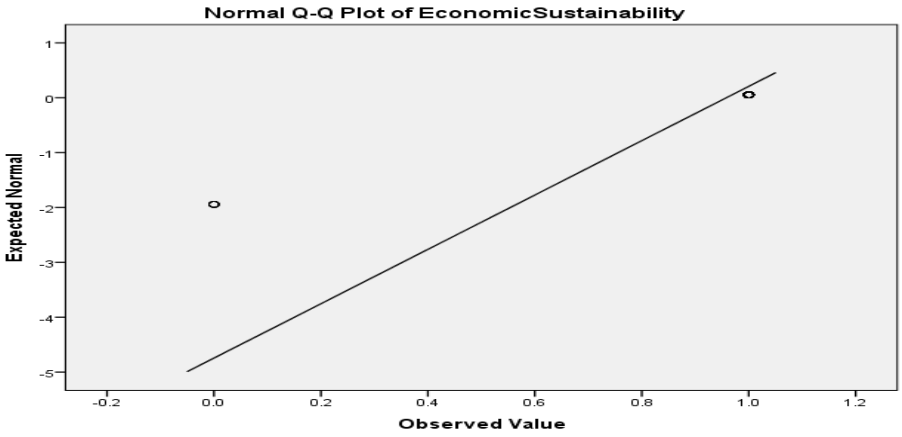


Figure 5.1 Non-Normal Distributed Data of Economic Sustainability

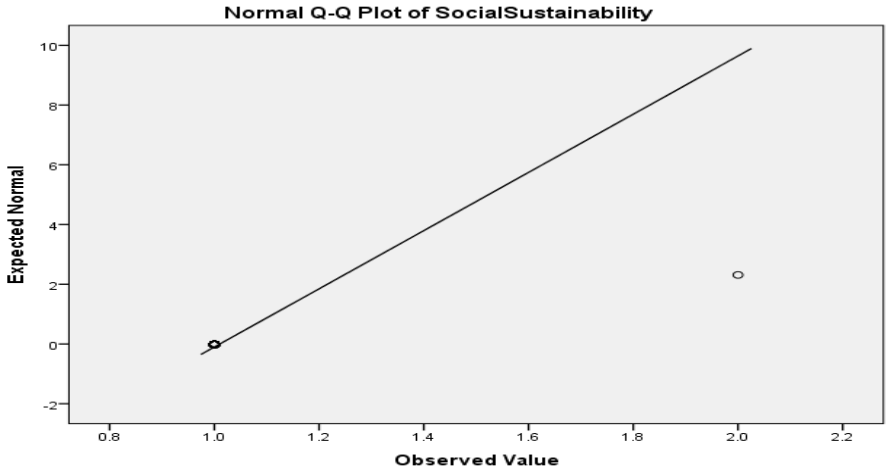


Figure 5.2 Non-Normal Distributed Data of Social Sustainability

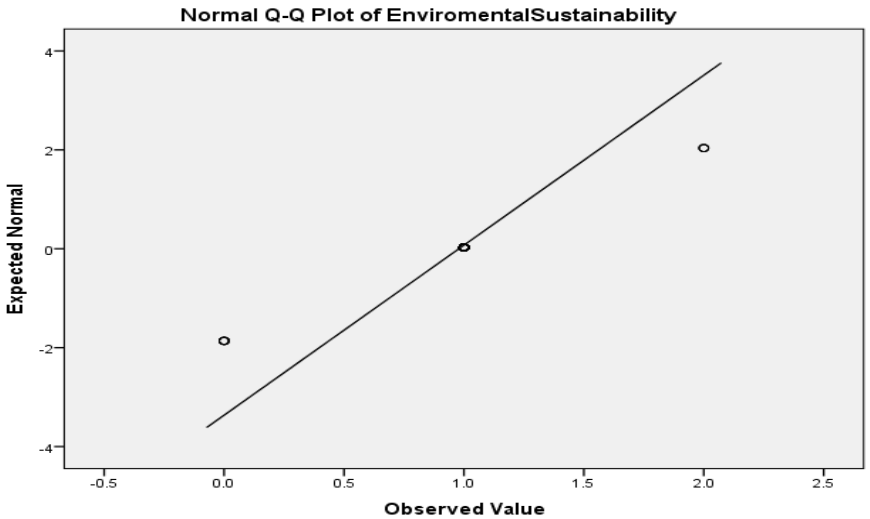


Figure 5.3 Non-Normal Distributed Data of Environmental Sustainability

5.5. Testing Regressions Assumptions

This section delves into the exploration and confirmation of regression assumptions for the conducted models, with a focus on autocorrelation and heteroscedasticity.

Autocorrelation pertains to the extent of correlation between values of the same variables across different observations within the dataset (Garson, 2012). In this study, three dependent variables are considered: economic, environmental, and social sustainability. To assess autocorrelation, the Durbin-Watson test was employed. This statistical test evaluates the null hypothesis that residuals do not exhibit autocorrelation against the alternative hypothesis where residuals demonstrate an autocorrelation pattern. Examination of the Durbin Watson Tables for lower and upper critical values at K=5 regressions revealed the values dL = 1.577 and dU = 1.778. Since all the results across the specified models are both greater than and less than 1.778, the null hypothesis of no autocorrelation is upheld. This indicates the absence of autocorrelation issues.

Durbin-Watson values for Economic sustainability = 2.096

Durbin-Watson values for Social Sustainability = 1.792

Durbin-Watson values for Environmental sustainability = 1.562

Homoscedasticity Assumption: Homoscedasticity refers to a scenario in which the error term (the random fluctuation in the relationship between independent variables and the dependent variable) remains consistent across all values of the independent variables (Garson, 2012). In line with this assumption, the scatter plot of standardized residuals against unstandardized predicted values was employed to visually assess it. Figures 5.4, 5.5, and 5.6 depict the scatter plots illustrating the relationships between the independent and dependent variables. The displayed patterns reveal that the data points are dispersed evenly. Consequently, no indications of heteroscedasticity are evident, affirming that the relationships among variables adhere to the principle of homoscedasticity.

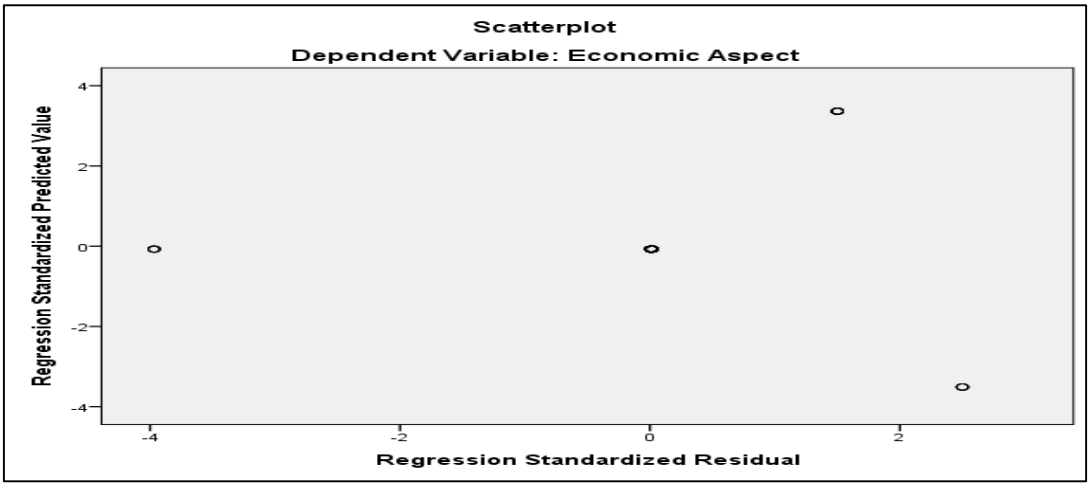


Figure 5.4 Scatter Plot for Heteroscedasticity (Economic Aspect)

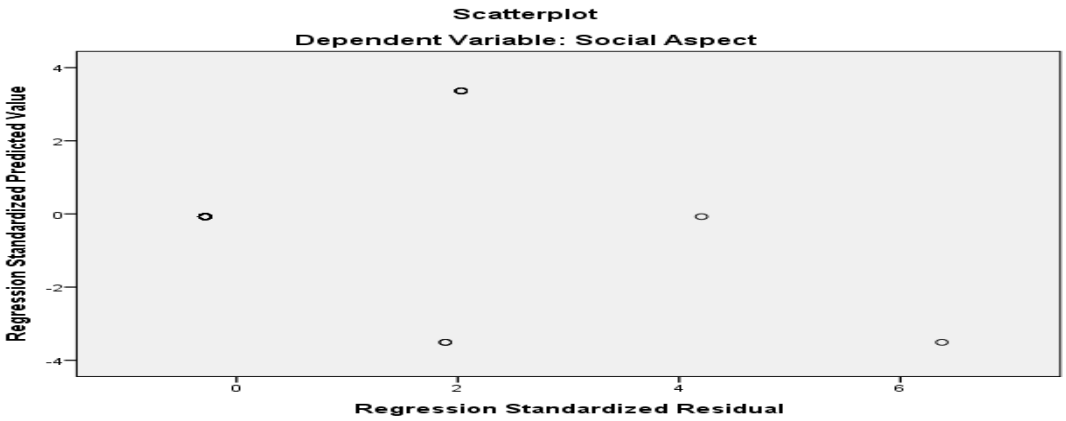


Figure 5.5 Scatter Plot for Heteroscedasticity (Social Aspect)

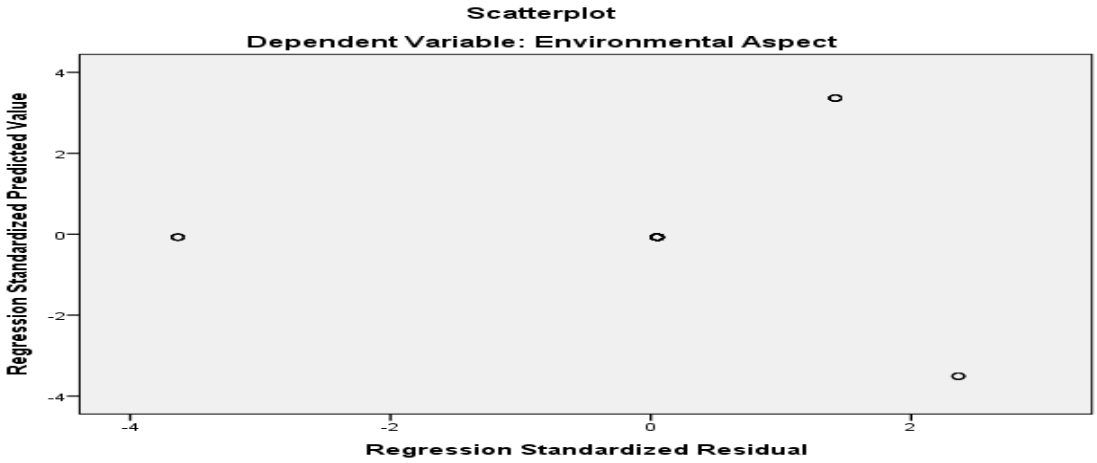


Figure 5.6 Scatter Plot for Heteroscedasticity (Environmental Aspect)

5.6. Relationships between Research Variables

In this section, the survey responses are subjected to analysis, focusing on the interrelationships between the independent variables (X) and dependent variables (Y) through correlation and regression analyses.

5.6.1 Testing the First Hypothesis - the relationship between Technology Adoption and the improvement of the Economic Aspect

Table 5.6 shows the correlation coefficient between telecommunication and intelligent applications, cargo owner applications, driver applications and economic sustainability improvement. It was observed that:

- There is a significant relationship between telecommunications and intelligent applications and the economic aspect improvement, as the corresponding P-value is less than 0.01 (P-value = 0.000) (see Table 5.6). Also, the variables are positively correlated as the correlation coefficient is greater than zero (r = 0.879).
- There is a significant relationship between cargo owner applications and the economic aspect improvement, as the corresponding P-value is less than 0.01 (P-value = 0.000) (see Table 5.6). Also, the variables are positively correlated as the correlation coefficient is greater than zero (r = 0.828).
- There is a significant relationship between driver applications and the economic aspect improvement, as the corresponding P-value is less than 0.01 (P-value = 0.000) (see Table 5.6). Also, the variables are positively correlated as the correlation coefficient is greater than zero (r = 0.935).

Table 5.6 Correlation Analysis of the effect of Technology Adoption on the Economic Aspect

			Economic Aspect
	Telecommunication and Intelligent Applications	Correlation Coefficient	.879**
		P-value	.000
		N	95
	Cargo Owner Applications	Correlation Coefficient	.828**
		P-value	.000
		N	95
	Driver Applications	Correlation Coefficient	.935**
		P-value	.000
		N	95

By constructing the simple regression model in Table 5.7, in which the Economic Aspect is the dependent variable, the results show that there is a positive significant effect of telecommunication and intelligent applications, cargo owners applications, drivers' application and the economic aspect improvement, as the P-values are all less than 0.01 (P-value = 0.000) (see Table 5.4), with coefficients equal to 0.969, 0.788 and 0.823 respectively ($\beta > 0$).

Table 5.7 Regression Analysis of the effect of Technology Adoption on the Economic Aspect

		Unstandardized Coefficients		Standardised Coefficients		
Model		B	Std. Error	Beta	T	P-value
1	(Constant)	.949	:.090		10.534	.000
	Telecommunication and Intelligent Applications	.969	.090	.931	10.739	. 000
	Cargo Owner Applications	.788	.153	.712	8.270	. 000
	Driver Applications	.823	.166	.750	9.225	. 000

Therefore, H_1. "An increase in Technology Adoption will improve the economic aspect" is fully supported.

5.6.2 Testing the Second Hypothesis - The relationship between Technology Adoption and the improvement of the Social Aspect

Table 5.8 presents the correlation among telecommunication and intelligent applications, cargo owner applications, driver applications, and the social aspect. The findings indicate that:

- An insignificant relationship is observed between telecommunication and intelligent applications and the improvement in the social aspect, given that the corresponding P-value exceeds 0.05 (P-value = 0.239) (refer to Table 5.8). Furthermore, the variables exhibit a positive correlation, with a correlation coefficient greater than zero (r = 0.122).
- A significant relationship is identified between cargo owner applications and the enhancement of the social aspect, as indicated by a P-value of less than 0.01 (P-value = 0.000) (see Table 5.8). Additionally, the variables display a positive correlation, with a correlation coefficient greater than zero (r = 0.639).
- Likewise, a significant relationship is established between driver applications and the improvement in the social aspect, with a P-value lower than 0.01 (P-value = 0.000) (see Table 5.8). The variables also demonstrate a positive correlation, reflected by a correlation coefficient greater than zero (r = 0.438).

Table 5.8 Correlation Analysis for the Relationship between Technology Adoption and the Social Aspect

			Social Aspect
	Telecommunication and Intelligent Applications	Correlation Coefficient	.122
		P-value	.239
		N	95
	Cargo Owner Applications	Correlation Coefficient	.639**
		P-value	.000
		N	95
	Driver Applications	Correlation Coefficient	.438**
		P-value	.000
		N	95

By formulating the simple regression model outlined in Table 5.9, with the social aspect serving as the dependent variable, the outcomes reveal a noteworthy positive and significant influence of telecommunication and intelligent applications, cargo owner applications, and driver applications on the enhancement of the social aspect. This assertion is substantiated by a P-value below 0.01 (P-value = 0.000), accompanied by coefficients of 0.333, 1.116, and 0.504 ($\beta > 0$).

Table 5.9 Regression Analysis of the effect of Technology Adoption on the Social Aspect

Model		Unstandardized Coefficients		Standardised Coefficients		
		B	Std. Error	Beta	T	P-value
	(Constant)	.772	.079		9.825	.000
	Telecommunication and Intelligent Applications	.333	.078	.369	4.250	.000
	Cargo Owner Applications	1.116	.134	1.308	8.351	.000
	Driver Applications	.504	.144	.523	3.491	.001

Therefore, H_2"An increase in the adoption of technology causes an improvement in the social aspect" is fully supported.

5.6.3 Testing the Third Hypothesis - The relationship between Technology Adoption and the Environmental Aspect

Table 5.10 displays the correlation coefficients among telecommunication and intelligent applications, cargo owner applications, driver applications, and the enhancement of the environmental aspect. The findings indicate that:

- A significant relationship is observed between telecommunication and intelligent applications and the improvement in the environmental aspect, with a corresponding P-value below 0.05 (P-value = 0.012) (refer to Table 5.10). Additionally, the variables exhibit a positive correlation, as reflected by a correlation coefficient greater than zero (r = 0.256).
- A significant relationship is found between cargo owner applications and the enhancement of the environmental aspect, given that the corresponding P-value

is less than 0.01 (P-value = 0.000). Moreover, the variables display a positive correlation, with a correlation coefficient greater than zero (r = 0.364).

- Similarly, a significant relationship is identified between driver applications and the improvement in the environmental aspect, as evidenced by a P-value below 0.01 (P-value = 0.008) (see Table 5.10). The variables also demonstrate a positive correlation, with a correlation coefficient greater than zero (r = 0.269).

Table 5.10 Correlation Analysis of the effect of Technology Adoption on the Environmental Aspect

			Environmental Sustainability
	Telecommunication and Intelligent Applications	Correlation Coefficient	.256*
		P-value	.012
		N	95
	Cargo Owner Applications	Correlation Coefficient	.364**
		P-value	.000
		N	95
	Driver Applications	Correlation Coefficient	.269**
		P-value	.008
		N	95

By constructing the simple regression model presented in Table 5.11, with environmental sustainability as the dependent variable, the findings indicate the following relationships:

- There exists a positive but insignificant effect of telecommunications and intelligent applications on the environmental aspect, evidenced by a P-value exceeding 0.05 (P-value = 0.552). The coefficient for this effect is 0.071 ($\beta > 0$).
- Additionally, a positive and significant relationship is observed between cargo owner applications, driver applications, and the enhancement of the environmental aspect. The corresponding P-values are less than 0.05 (P-value = 0.016 and 0.020 respectively), and the coefficients are 0.500 and 0.250 ($\beta > 0$).

Table 5.11 Regression Analysis of the effect of Technology Adoption on the Environmental Aspect

Model		Unstandardized Coefficients		Standardised Coefficients		
		B	Std. Error	Beta	T	P-value
	(Constant)	.643	.120		5.358	.000
	Telecommunication and Intelligent Applications	.071	.120	.071	.597	.552
	Cargo Owner Applications	.500	.204	.529	2.452	.016
	Driver Applications	.450	.220	.434	2.134	.020

Therefore, H_3"An increase in the adoption of technology will improve the environmental aspect" is partially supported.

Based on the findings derived from the analysis, it is evident that technology exerts a notable and affirmative influence on the dimensions of sustainability, namely economic, social, and environmental. This observation suggests that with an increase in the adoption of technology applications and innovative practices, companies are able to mitigate challenges, bolster their performance, and foster positive advancements in the realms of sustainability.

The outcomes underscore that the integration of technological applications yields a direct and constructive impact on the various facets of sustainability—economic and social aspects (fully supported), as well as the environmental aspect (partially supported). Additionally, the research hypotheses formulated have undergone rigorous testing and validation.

In summation, the study concludes that the variables encompassed within the proposed road freight transport performance measurement framework exhibit validity, the chosen sample size proves adequate, the interrelationships among the variables demonstrate significant positivity and correlation, and ultimately, the survey attains its objective by effectively testing the proposed road freight transport performance measurement framework.

5.7. A Roadmap for Adopting the Proposed Road Freight Transport Performance Measurement Framework in the Egyptian Context

Focus groups were conducted within this research to outline a roadmap for the implementation of the proposed road freight transport performance measurement framework within the Egyptian context. Furthermore, an exploration into the barriers and challenges that may hinder the adoption of this framework by Egyptian road freight transport companies was undertaken. The collected data from the focus groups underwent analysis using thematic and content analyses, facilitated by the extraction of codes through NVivo software, tailored specifically for qualitative analysis.

The subsequent section details the formulation of questions for the focus groups, delineates the criteria governing the selection of road freight transport companies for the focus group sessions, and outlines the intended outcomes sought from each question.

5.7.1. Focus Groups Questions Design

Three freight forwarding companies were carefully chosen to partake in the focus group sessions. Each focus group was composed of key personnel including a quality manager, logistics and transport manager, operations manager, financial manager, and a professional driver. Companies expressing their willingness to participate in the research received a focus group protocol (refer to Appendix 2). The layout of the focus group questions and the specific desired outcomes for each question are comprehensively depicted in Table 5.12.

Table 5.12 The Outputs Targeted from the Focus Group Questions

Question	Output
Q1: According to previous studies on the road freight transport industry, a performance measurement system has been developed to investigate the impact of measuring road freight transport on improving the road freight transport companies' performance through the aspects of sustainability. From your own point of view, how can this performance measurement system assist in measuring company performance?	This question is designed to elicit diverse perspectives on the adoption and implementation of the proposed road freight transport performance measurement framework, as well as to ascertain its role in measuring various company activities.
Q2: From your experience in the road freight transport industry, what are the challenges and obstacles standing against applying the developed road freight transport framework?	The intention behind this question is to delve into the potential hindrances that could impede the application of the proposed road freight transport performance measurement framework.
Q3: Based on your answers to Question 2, how could these challenges and obstacles be overcome?	The objective of this question is to identify an array of solutions and viewpoints for addressing potential challenges.
Q4: From your own point of view, is there any further information you wish to add?	This is an open question, allowing participants to contribute any crucial information or suggestions aimed at enhancing the proposed road freight transport performance measurement framework.

5.7.2. Data Process Analysis

A thematic analysis approach was employed to analyse the data derived from the three focus groups, enabling the extraction of key themes and codes for categorization. The collected data were transcribed, preliminary codes were generated, and themes were identified and interpreted, culminating in the development of a comprehensive report. Moreover, word frequency clouds, tree-mapping, and cluster analysis were generated

to enhance data visualization. In this research, NVivo software was employed as an effective tool for analysing qualitative data, offering researchers valuable insights for code analysis and categorization based on participants' responses (Maguire et al., 2017).

The process of analysing and interpreting the data from the three focus groups involved the following six main steps. These steps proved to be highly instrumental in structuring a framework for the identified themes, codes, and categories (Berlanda et al., 2020). Thus, the adopted steps are outlined as follows:

1st step: Being Familiar with the Data Collected
2nd step: Generating Initial Codes

3rd step: Searching for Themes

4th step: Reviewing the Themes

5th step: Defining the Themes

6th step: Reporting the Results

1st step: Being Familiar with the Data Collected:

The data obtained from the focus groups is meticulously recorded, manually transcribed, and securely stored as a Word file. Throughout this process, notes are diligently taken to document the observed points gleaned from the focus group discussions.

2nd step: Generating Initial Codes:

As previously mentioned, the collected data is analysed using NVivo software, which involves the creation of themes, codes, and categories based on the transcripts of participants' responses. To generate themes, the recorded data is transcribed, and common words recurring across different focus groups are identified and emphasized. Subsequently, the process involves importing the transcripts into NVivo software, where codes and nodes are established, and themes are developed in alignment with these codes.

3rd step: Searching for Themes:

Based on the themes identified within NVivo, notable terms frequently utilized, as indicated by the word cloud, encompass "road," "freight," "challenges," "obstacles," "technology," "problems," and "comprehensive performance measurement system." The utilization of tree-mapping further verifies the frequencies of these same words, as deduced from the word cloud. This mapping underscores terms such as "mapping," "quantifying," "innovative solutions," "identifying actions," and "sustainability." As a result, the subsequent section outlines the primary themes derived in connection to the nodes and word frequencies discerned from the transcripts of the interviews.

4th step: Reviewing the Themes:

During this phase, participants' responses are subjected to coding, wherein themes are established to correlate and pinpoint the categories outlined within the word frequency table. These identified themes serve to unveil the primary concepts articulated by the respondents. The extraction of these themes facilitates the exploration of codes and categories, allowing for discussions that interlink with the identified themes. This comprehensive process seeks to scrutinize the relationships among these elements and ultimately determine the essential focal points.

Notably, eighty percent of the themes emerged from the initial and second round of focus groups. These themes encompass "innovative solutions," "sustainability," "quantifying operations," and "identifying actions." Subsequently, ninety percent of the themes were generated subsequent to the third round of focus groups, comprising "mapping," "sustainability," and "innovative solutions."

The central themes identified within this sector encompass the repercussions of adopting a road freight transport performance measurement system, the principal challenges impeding the adoption of such a measurement system, the merits and demerits associated with the implementation of a road freight transport performance measurement system, as well as the formulation of recommended criteria aimed at mitigating challenges within this sector.

5th step: Defining the Themes:

Within this section, themes are distinctly delineated by associating them with their core categories. Each theme is systematically coded and cross-referenced in accordance with the participants' responses (refer to Table 5.13).

Table 5.13 Themes - Definition and Categorisation

No.	Themes	Categories	Codes	References
1	The impact of adopting the road freight transport performance measurement framework	Implementation of the proposed road freight transport performance measurement framework lessens problems.	1	40
2	Advantages and disadvantages of adopting PMS	**Advantages:** • Enhancing company performance towards sustainability • Measuring company performance and identifying problems • Improving decisions towards sustainability **Disadvantages:** • Increasing costs for road freight transport companies • Customer's perception towards PMS	2	35
3	The main challenges facing the adoption of a performance measurement system in this sector.	• Main obstacles, such as market competition, lack of execution plans for management, un-planned crisis, obsolete trucks, and scarcity of professional drivers. • The limitations of registered companies, absence of innovative solutions and lack of enforcing rules	3	45
4	Identifying recommended criteria to reduce challenges in this sector.	• Governmental rules • Road freight transport rules	4	50

The themes gleaned from the analysis of focus groups encompass the ramifications of adopting a road freight transport performance measurement system, the primary challenges confronted in adopting a performance measurement system within this sector, the benefits and drawbacks associated with the implementation of such a system, and the identification of suggested criteria to alleviate obstacles in this sector.

a. The Impact of adopting a Road Freight Transport Performance Measurement System (code 1)

The theme of “Application” (I) (code 1) has the category of the "implementation of the developed performance measurement system”, and it is shown to lessen problems. To conclude, the first theme shows that the implementation of the developed performance measurement system should assist in enhancing the road freight transport companies’ performance because it will help in reducing the identified problems towards sustainability.

b. Advantages and Disadvantages of adopting PMS (code 2)

The theme titled "Advantages and Disadvantages" (code 2) encompasses two primary categories.

Advantages:

Numerous benefits arise from the adoption of the road freight transport performance measurement system, including the augmentation of companies' performance in the sustainability domain, the measurement of companies' performances, the identification of issues, and the fostering of steps toward sustainability.

Disadvantages:

Certain drawbacks may emerge during the process of implementing the developed PMS, such as the substantial adoption cost for road freight transport companies and customer perceptions regarding PMS. These categories are established as the central components within this theme, derived from the insights provided by the participants.

c. The Main Impediments facing the adoption of a Performance Measurement System in this Sector (code 3)

The third theme to be presented is “Impediments” (M) (code 3) under which "obstacles" is the first category identified. It includes market competition, lack of technological adoption planning for management, contingencies for unplanned crises, obsolete trucks, and a scarcity of professional drivers. The second category identified under this theme is "limitations”, and it comprises the lack of registered companies, absence of innovative solutions and lack of enforcing rules.

d. Identifying Recommended Criteria to reduce Impediments in this Sector (code 4)

The fourth theme emerging from the analysis of participants' responses is "Recommended Criteria" (R) (code 4), primarily comprising two principal categories. The first category, labelled "Government Rule," entails collaborative efforts between the government and the private sector to provide driver training, offer support for technology adoption, standardize regulations, restructure the sector, establish tolls, and initiate campaigns aimed at altering driver culture. The second category, "Road Freight Transport Companies," encompasses measures such as setting regulations to shift customer perceptions towards prioritizing trip quality over cost, implementing a performance measurement system to assess and improve performance, and ensuring companies are duly registered.

Based on the feedback from interviewees, the proposed road freight transport performance measurement framework is anticipated to significantly enhance the operational performance of road freight transport companies in Egypt. This framework directly addresses key industry challenges, underscores the pivotal role of technology adoption in augmenting company performance, and encompasses a variety of recommended performance measurements to facilitate enhancement and sustainability. The interrelationships among the variables integrated within the proposed framework are emphasized, and the practical applicability of the proposed road freight transport performance measurement framework within Egyptian road freight transport companies is illustrated (refer to Figure 5.7). The subsequent section is dedicated to presenting the transcripts of the focus groups, wherein themes are developed through the utilization of thematic analysis.

The 6th step: Reporting the Results:

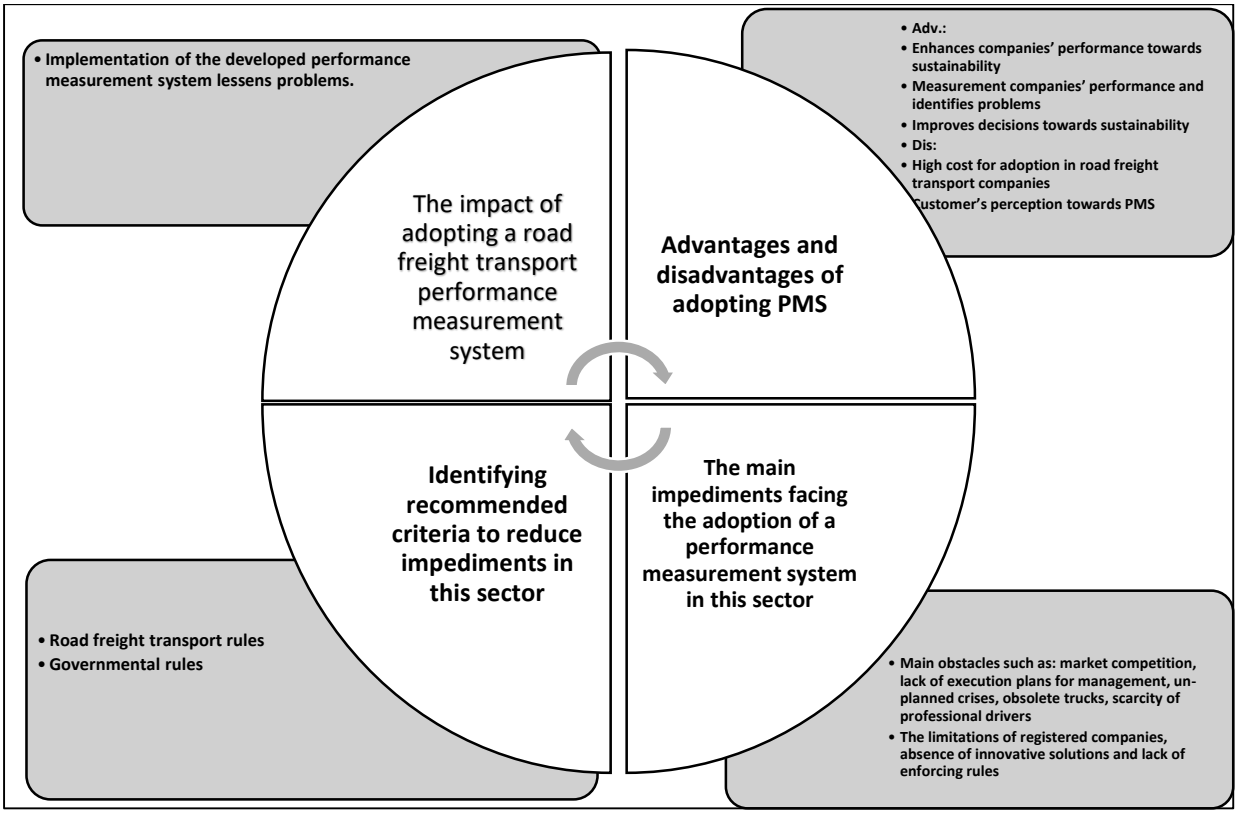


Figure 5.7 Themes and Categories related to demonstrating the Developed PMS

For the focus groups, the researcher targeted 15 respondents who are working in the road freight transport companies. Three focus groups were carried out, each with five respondents consisting of Logistics and Transport Managers, Quality Managers, Operations Managers, Financial Managers, and professional drivers). The focus groups were analysed using thematic and content analyses to extract the different points of view from the participants, to understand the main challenges and obstacles for applying the proposed road freight transport performance measurement framework, to investigate the impact of applying such a framework, and to present suggestions for reducing any barriers.

Code 1: The Impact of adopting a Road Freight Transport Performance Measurement System

The majority of respondents concurred that technology serves as a pivotal instrument in addressing challenges within road freight transport. Furthermore, it was widely acknowledged that technology enhances the efficiency of the road transport performance metrics system by facilitating the resolution of prevalent issues in the freight sector, ultimately leading to performance enhancement. Additionally, drivers emphasized the necessity for training to equip them with the skills to navigate the myriad challenges consistently encountered during the transportation of goods. For example, an operations manager from one company remarked: *"Technology as a main aspect of the developed system, it is very important, and it increases the efficiency of the proposed road freight transport performance measurement framework because applying technology will facilitate solving the problems faced by the road freight transport industry and enhance its performance" FG1*.

All respondents, a unanimous one hundred percent, concurred that technology holds a pivotal role in addressing the challenges confronted by road freight transport. This sentiment was underscored by its ability to augment the efficiency of the road transport performance metrics system, actively facilitating the resolution of complex issues encountered within the freight sector. This technological integration subsequently contributes to an overall enhancement in industry performance. Additionally, transport drivers emphasized the indispensability of training, enabling them to adeptly navigate the diverse challenges they consistently face during the transportation of goods. Notably, the quality manager within the third company stressed: *"technology as a main aspect of the developed system is very important and increases the efficiency of the proposed road freight transport performance measurement framework because applying technology will facilitate solving the problems faced by the road freight transport industry and enhance its performance" FG3*.

Code 2: Advantages and Disadvantages of adopting PMS

Most respondents recognised the presence of both advantages and disadvantages associated with adopting a PMS system.

The proposed performance measurement system for road transport within road freight transport companies is deemed worthy of adoption, primarily due to its ability to

empower managers and decision-makers in pinpointing operational issues. Simultaneously, the system facilitates the establishment of regulations and objectives geared towards overcoming these particular challenges and fostering performance enhancement. A senior-level manager expressed this sentiment, stating: *"my point of view toward your developed performance measurement system is that it should be considered as a comprehensive system. This is because it consists of various problems facing the sector from different angles, as a set of performance measurement to be used by different road freight transport managers" FG3.*

A shift in culture is imperative concerning truck drivers in Egypt, as succinctly expressed by a truck driver: *"one more point I wish to add is that the culture towards truck drivers in Egypt should be changed and our work should be more appreciated because our job is very stressful and needs qualified drivers" FG2.*

An overwhelming majority of respondents held the belief that the proposed road freight transport performance measurement framework should serve as a valuable tool for road freight transport companies, aiding them in gauging their performance. Additionally, it was seen as a resource to aid decision-makers in identifying operational-level challenges, thereby facilitating the formulation of strategies and the establishment of goals aimed at effectively overcoming these identified issues. A Financial Manager offered insight, stating: *"My point of view toward your developed performance measurement system is that it should be considered as a comprehensive system. This is because it includes various problems facing the sector from different angles, and a set of performance measurement are identified to be used by different road freight transport managers" FG1.*

A cultural shift is imperative when it comes to the perception of truck drivers in Egypt. The truck driver from the third company elaborates: *"the culture towards truck drivers in Egypt should be changed and our work should be more appreciated because our job is very stressful and needs qualified drivers" FG3.*

Code 3: The Main Impediments facing the adoption of a Performance Measurement System in this Sector

The majority of respondents highlighted challenges and obstacles impeding the implementation of the developed road freight transport framework. An absence of rules and regulations governing the road transport sector in Egypt emerged as a key concern, as articulated by a Logistics and Transport Manager: "*I am certain that the absence of the rules and regulations for managing the road freight transport sector in Egypt will be the main challenge you will face" FG3.*

Concerning the Egyptian market's culture, competition primarily revolves around trip cost rather than trip quality. This sentiment was conveyed by a Logistics and Transport Manager who stated: *"most customers are looking for reducing the trip cost as much as they can rather than caring about the trip quality and the performance of the driver. Consequently, this is one of the main obstacles that you are going to face when applying your developed system" FG1.*

Regarding the shortage of professional drivers, the Quality Manager from the second company remarked: *"one main obstacle I will add to all the above-mentioned ones is the scarcity of professional drivers, even though the dependency on the professional drivers is high. However, we have work for longer time with limited hours of rests" FG2.*

Ninety-five percent of respondents identified a key challenge in applying a road freight transport framework as the insufficient enforcement of rules and regulations governing the road transport sector in Egypt. This sentiment was echoed by a Financial Manager who noted: "*the lack of enforcing the rules and regulations for managing the road freight transport sector in Egypt will be the main challenge you will face" FG1.*

Concerning the Egyptian market's culture, competition is predominantly centred on trip cost rather than trip quality. A noteworthy remark by the Financial Manager from the third company is: *"Most of the customers are looking more for a reduction in the trip cost as much as they can rather than focussing on the trip quality and the performance of the driver. Consequently, this is one of the main obstacles which you are going to face when applying your developed system" FG3.*

In relation to the shortage of professional drivers, an operations Manager stated: *"The scarcity of professional drivers and the dependency on professional drivers are high. Hence, we are forced to work for a longer time with limited hours of rest" FG2.*

Unforeseen circumstances and crises, including the impact of events like COVID-19 which have adversely affected the entire industry, also pose obstacles to the sector's advancement. This sentiment was succinctly captured by a Logistics and Transport Manager who stated: *"the existence of crises, such as the Coronavirus, impacts the industries and supply chains negatively" FG1.*

Code 4: Identifying Recommended Criteria to reduce Impediments in this Sector

All participants provided insights into overcoming the challenges confronting the sector. One participant stated: *"the government in Egypt is about to launch new rules and regulations for the road freight transport sector. Therefore, if these rules are applied accurately and unified for all the Egyptian road freight transport companies, this sector will be enhanced" FG1.*

Customers ought to prioritize trip quality over trip cost, enabling the exploration of additional applications and technological enhancements to elevate trip quality. A respondent emphasised: *"customers should focus more on the trip quality rather than trip cost, to give us the chance to look forward for more technological apps and features that ought to increase trip quality*" *FG2.*

Furthermore, there was a recognition of the need for enhanced training and cultural awareness among transport drivers. One participant emphasised: *"I see that drivers need more care and more training, and the culture needs to be changed towards our job in order to overcome the problem of driver scarcity" FG3.*

Most participants' suggestions for surmounting these challenges and obstacles include the imminent establishment of rules and regulations for the road freight sector by the Egyptian government. *"The government in Egypt is about to launch rules and regulations for the road freight transport sector. Therefore, if these rules are applied accurately and unified for all the Egyptian road freight transport companies, this sector will be enhanced" FG3.*

Customers should prioritize trip quality over trip cost, thereby affording managers the opportunity to explore additional applications and technological features aimed at enhancing trip quality: *"customers should focus more on the trip quality rather than*

trip cost to give us the chance to look forward to adopting more technological apps and features that ought to increase trip quality" FG*1*.

Transport drivers require enhanced training, and there is a need to shift the cultural perspective towards this profession. As one participant highlighted: *"I see that drivers need more care, more training and the culture needs to be changed toward our job in order to overcome the problem of drivers' scarcity" FG2.*

Based on participants' responses, it can be concluded that key solutions recommended to overcome barriers in introducing the proposed performance measurement framework in Egyptian road freight transport companies involve government collaboration with these companies to restructure the sector, enforce and standardize regulations, maintain road infrastructure, enhance driver training for innovative trucks, and encourage customers to prioritize trip quality. This approach aims to motivate companies to invest in adopting technological apps and performance measurement systems. The figure below (Figure 5.8) provides a visual summary of the recommended roadmap for implementing the proposed road freight transport performance measurement framework in Egypt. It highlights the main challenges, proposed solutions, and recommendations from respondents.

The roadmap for road freight transport performance measurement may encompass the following steps:

1. Define the Performance Measurement Objectives: Clearly outline the goals of measuring road freight transport performance, identifying areas such as delivery times, costs, safety, and environmental impact.
2. Select Key Performance Indicators (KPIs): Choose the essential metrics that align with the defined objectives. Examples may include on-time delivery rate, cost per mile, accidents per mile, and emissions per mile.
3. Create a Data Collection Strategy: Develop a plan detailing what data to collect, how to gather it, and who will be responsible. This plan should encompass delivery times, costs, accidents, emissions, vehicle and driver information, and route details.
4. Implement the Data Collection Plan: Put the data collection strategy into action, ensuring accurate and consistent data acquisition.

5. Analyse Collected Data: Apply statistical methods to evaluate the data and measure performance against the selected KPIs.
6. Communicate Results: Share the findings of the performance measurement with relevant stakeholders, including trucking companies, shippers, government entities, and customers.
7. Utilise Results for Enhancement: Utilize the insights gained from the measurement to identify improvement areas and formulate strategies to enhance performance.
8. Continual Measurement and Enhancement: Regularly repeat the performance measurement process to monitor progress, make necessary adjustments, and continuously enhance road freight transport performance.

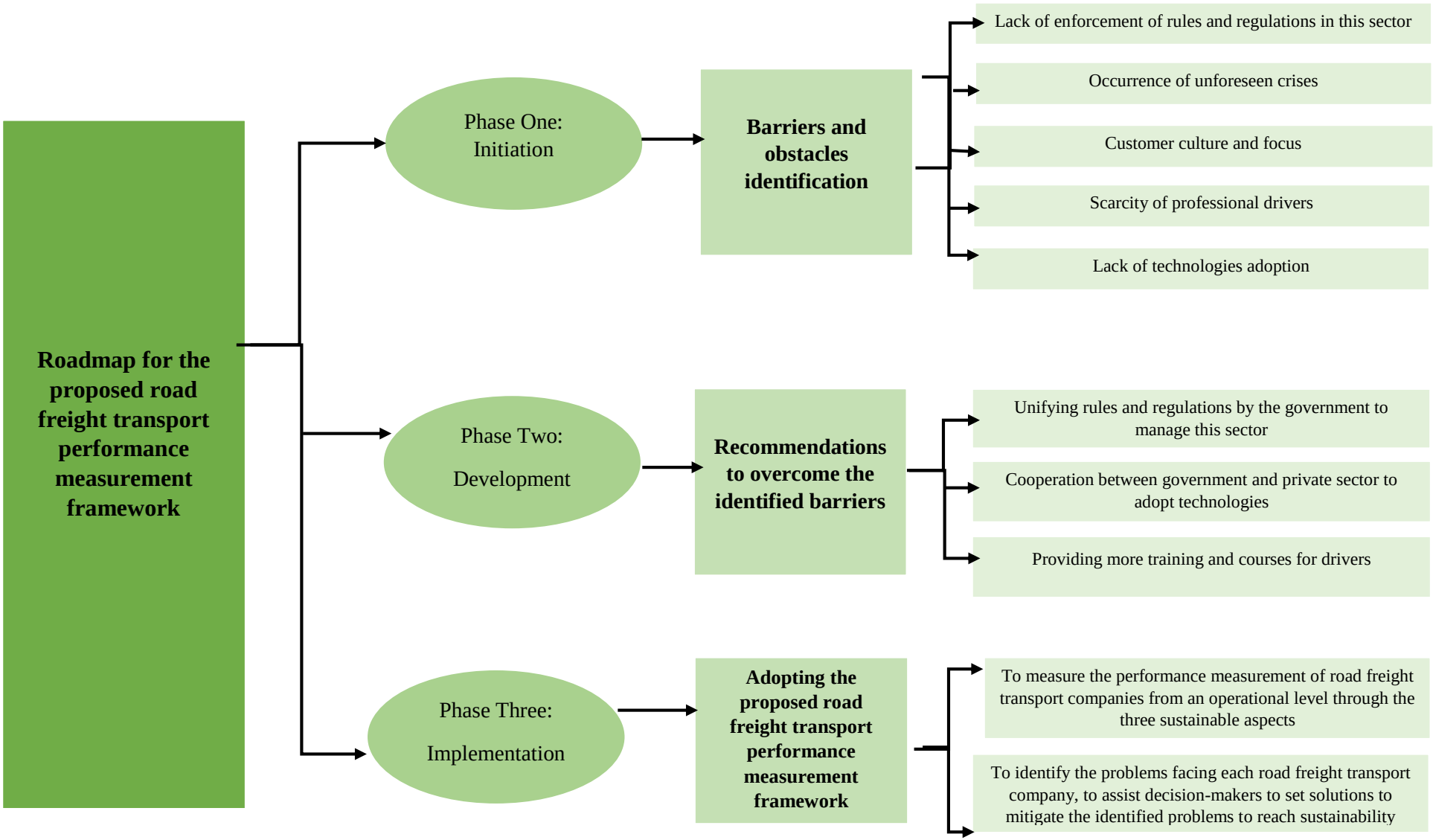


Figure 5.8 Roadmap for adopting the Proposed Road Freight Transport Framework

5.8. Summary

This chapter presents an analysis of survey responses and the empirical study conducted within the Egyptian road freight transport sector. The target was to collect two hundred surveys, with a 95 percent response rate from participants. The survey underwent a pilot test, followed by assessments of content, construct, and convergent validity to ensure data adequacy and validity. While the data were not normally distributed, they were found to be close to the mean. A regression analysis was employed to explore relationships between variables within the proposed road freight transport performance measurement framework. The analysis reveals a significant positive correlation between the variables and technology adoption, which is expected to directly impact sustainable aspects.

Furthermore, this chapter includes an analysis of focus groups conducted within various Egyptian road freight transport companies. The aim was to develop a roadmap for implementing the proposed road freight transport performance measurement framework in the Egyptian context. This analysis involved discussions on potential obstacles and challenges to adoption within the sector, along with suggested solutions to address them.

The subsequent chapter delves into the research findings from each phase of the study, addressing research questions and fulfilling the objectives of the research proposition.

CHAPTER SIX: FINDINGS AND DISCUSSION

6.1. Introduction

This chapter centres on a comprehensive discussion of the research findings obtained from each phase of the study. It aims to validate the research hypotheses formulated in Chapter Three and to compare the outcomes derived from the different research phases. Furthermore, the evaluation, analysis, and comparison of the developed road freight transport performance measurement framework within the Egyptian context are conducted in this chapter. This assessment is juxtaposed with the road freight transport performance measurement framework extracted from the literature review. Ultimately, the chapter culminates in a conclusive summary of its contents.

6.2. Research Findings

After reviewing the literature, it becomes evident that the reliance on road freight transportation is on the rise. However, this reliance carries various negative consequences that directly and indirectly impact the long-term performance of road freight transport companies (Rai et al., 2017; Ambrosino et al., 2019). Factors such as gas emissions, infrastructure, vehicle maintenance, and driver training and certifications, and traffic congestion need to be considered (Pathak et al., 2019; Kumar et al., 2019). This highlights a research gap, as a comprehensive road freight performance measurement system incorporating technology and encompassing the three dimensions of sustainability is lacking (Carlan et al., 2019; Mehdizadeh et al., 2019). Moreover, the integration of multiple performance indicators for a holistic evaluation of various road freight transport companies from a long-term perspective is still lacking (Kumar et al., 2019; Zavalko, 2018; Tobogu et al., 2018).

It has been noted that technology utilization can mitigate adverse consequences and enhance the sustainability-focused performance of road freight transport businesses (Carlan et al., 2019; Mehdizadeh et al., 2019; Choudhary et al., 2020).

To achieve the study objectives, a mixed-methods approach is employed, with each research phase tailored to address specific issues or goals. The Delphi approach is initially used to develop a conceptual road freight transport performance measurement framework aligned with the business context and assess the Egyptian road freight transport sector's current state. Following the Delphi round analysis, a survey is refined to explore correlations among identified study variables, test formulated research

hypotheses, and establish the applied road freight transport performance measurement framework. Lastly, focus groups convene to propose a roadmap for implementing the developed road freight transport performance measurement framework.

The three research phases in this study target distinct objectives, enabling the realization of research goals and the addressing of identified questions. The analysis of each research phase yields results that meet the research objectives and provide clear answers to the research questions. Consequently, the primary research aim has been successfully achieved.

Phase 1: Results and Analysis

Phase 1 results underscore the escalating significance of road freight transport, contributing substantially to national economies (Campos et al., 2019; ERTRAC, 2019). Key sustainable issues within road freight transport encompass congestion, infrastructure maintenance (with combined economic and environmental repercussions), and driver training and qualifications (associated with direct negative social impacts) (Road Freight Transport Statistics, 2019; Anwar et al., 2020). Moreover, the adoption of technologies in the sector is constrained by the high investment requirements, posing challenges for many companies and countries, despite the acknowledged potential to enhance sustainability-focused road freight transport performance (Carlan et al., 2019).

The findings also unveil existing performance measurement systems for road freight transport companies. However, these systems often address only one or two sustainability aspects, predominantly focusing on strategic-level measurements. Comprehensive performance measurement systems specifically designed for operational-level assessment of road freight transport companies remain limited (Tian et al., 2020; UNCTAD, 2017).

Conclusively, the alignment between the literature review and real-world observations is evident, as most participants concur on the identified problems' impact on the sector's performance. Additionally, participants recognize the role of technology adoption in the sector, constrained by insufficient rule enforcement, high investment demands, driver training gaps in technological adaptation, and customer preference for lower transport costs over trip quality.

Another noteworthy outcome from this phase is the demand for a performance measurement framework tailored to assess road freight transport companies. This framework should outline the key performance indicators essential for evaluating various companies. Notably, participants propose an array of performance measurements, some aligning with the literature review while others arise from participants' perspectives.

While numerous road freight transport companies fall within the small and medium-sized enterprise category, many are unable to embrace costly technological apps that could enhance performance management. These challenges stem from the substantial investment required. Notably, international and freight forwarding companies contribute significantly to Egypt's revenues, demonstrating up to a 9.0% revenue increase in 2018 based on economic statistics (Egypt Freight Transport & Shipping Report, 2018). Additionally, heightened reliance on E-shopping has further elevated transportation demand. This phase has achieved the first research objective through the development of a theoretical framework derived from the literature review.

Phase 2: Results and analysis

Phase 2 findings revealed that a notable challenge in the Egyptian road freight transport market is its pronounced fragmentation. Dominance within the sector is concentrated among major companies, largely attributed to their scale and operations.

The outcomes indicate that the implementation of the developed road freight transport performance measurement system is poised to guide decision-makers in problem identification and subsequent strategic planning to mitigate adverse impacts, ultimately advancing sustainability. Furthermore, this phase underscores the pivotal role of technologies in problem reduction. Consequently, a business-context-adapted conceptual framework has been crafted, marking the attainment of the second research objective.

With the accomplishment of the first and second objectives following the completion of phases one and two, the research questions (1st and 2nd) have been effectively addressed.

Phase 3: Results and Analysis

The analysis of the third research phase, encompassing surveys to assess the correlation among variables in the developed road freight transport performance measurement system (see Table 6.1), unveils direct positive relationships between technology adoption, performance measurement, and reduced sustainability-related issues. This confirms the testing and validation of the proposed road freight transport performance measurement framework. Thus, the third research objective has been successfully fulfilled, providing a clear response to the third research question.

Table 6.1 provides an overview of how the research hypotheses were examined and succinctly summarises the outcomes of the hypothesis testing.

Table 6.1 Research Hypotheses Testing and Results

Hypothesis	Hypothesis formulation		Hypothesis measurement	Results
	Literature review	Delphi rounds		
Independent variable: Technology Utilisation	√	√	Through surveys' statements developed according to the findings of the literature review and Delphi rounds conducted.	There is a significant relationship between technology utilisation and sustainable aspects (see Chapter Five).
Telecommunication and Information Technologies (IT)	√	√		
Cargo Owner Apps	√	√		
Driver Apps	√	√		
Dependent variables: Sustainable Road Freight Transport	√	√	Using a 3-point scale (agree (1), disagree (2), not sure (3)) (see Appendix 3).	By increasing the utilisation of technology, sustainable aspects will be improved.
Economic Aspect (congestion reduction, infrastructure maintenance)	√	√	Adopting correlation and multi-regression analysis to test relationships between the variables.	H_1 has been fully supported (see Chapter Five).
Environmental Aspect (congestion reduction, infrastructure maintenance)	√	Infrastructure maintenance ×		H_2 has been partially supported (see chapter five).
Social Aspect (driver's performances)	√	√		H_3 has been fully supported (see Chapter Five).

Phase 4: Results and Analysis

In this phase, the results of the focus groups have been analysed, summarizing the main challenges and obstacles that may hinder the adoption of the proposed road freight transport performance measurement framework within the Egyptian context. Additionally, participants in this phase provided various recommendations to surmount these obstacles and facilitate the adoption of the proposed framework.

As a result, a roadmap has been devised for the implementation of the applied road freight transport performance measurement framework within the Egyptian context. Furthermore, the research questions (4th and 5th) have been unequivocally addressed, thus achieving the 4th research objective. The following section presents a discussion comparing the outcomes of the literature review with the results obtained from other research phases.

6.3. Practical Results and Implications

In the preceding sections, the principal research findings derived from each research phase have been elaborated upon. Within these phases, the research questions, research objectives, and overarching research aim have been comprehensively addressed and met. Consequently, this section undertakes a comparative analysis between the outcomes gleaned from the literature review and the findings garnered from diverse research methods, namely semi-structured interviews, surveys, and focus groups.

6.3.1. Road Freight Transport Problems

The main issues identified from prior studies encompass congestion, infrastructure maintenance, and driver qualifications and training (Chen et al., 2018; Kellner et al., 2019). Additionally, the occurrence of epidemics, such as COVID-19, poses significant risks to truck drivers and exposes them to infections (Dvorak et al., 2020). These challenges have direct and negative sustainable impacts, influencing the performance of the road freight transport sector (Islam et al., 2013; ERTRAC, 2019; Road Freight Transport Statistics, 2019). Moreover, these problems manifest direct economic, environmental, and social consequences on both the sector and the performance of road freight transport companies (Piecyk et al., 2010; Lin-xue et al., 2015; Besselink et al., 2016; Mommens et al., 2016).

In Egypt, a prominent challenge faced by the road freight transport sector is the high and escalating accident rates (El-Husseiny et al., 2017). Addressing this, the government's focus should extend to road infrastructure maintenance, truck driver training, enforcement of sector-related laws, and active participation in road transport conventions to ensure safe and efficient international cargo transportation (Egypt's Provision Risk Report, 2018). The failure to adopt technological applications for managing and tracking trucks during freight transportation diminishes safety levels while elevating corruption instances and accident occurrences (Zaki et al., 2019; El-Husseiny et al., 2017). Terrorism acts also cast a shadow on trade in Egypt, particularly within road transport, with North Sinai witnessing limited cargo transportation due to security concerns (Nosseir, 2016).

Moreover, the scarcity of skilled professional truck drivers exacerbates the situation. Well-trained drivers capable of handling diverse cargo types can effectively adapt to new technological applications and innovative trucks (Zaki et al., 2019; El-Husseiny et al., 2017). Fuel shortages lead to fluctuating fuel prices and elevated journey costs (Egypt's Provision Risk Report, 2018). Congestion, especially during peak hours, curtails truck performance, raises fuel consumption, and escalates acceleration rates (Nosseir, 2016). The lack of technology adoption results from inadequate infrastructure, necessitating substantial investments and funding for improvements (Egypt Logistics Risk Report, 2020).

In summation, road freight transport holds paramount significance for a nation's economy. However, its reliance is associated with a plethora of challenges, including accidents, congestion, inadequate infrastructure, pollution, and safety concerns. These impediments hinder the attainment of sustainability (Holguín-Veras et al., 2016). Furthermore, road freight transport contributes significantly to the emission of negative externalities, underlining the need for transportation policymakers to address factors that enhance the sector, encompassing infrastructure maintenance and strategies to alleviate traffic congestion (Engstorm, 2016).

The empirical study findings have substantiated the road freight transport sector's issues identified in the literature review. Participants confirmed the following challenges:

"There are various problems facing the road freight transport sector, such as the congestion problems resulting from the allowance period for the movement of trucks in Egypt" P3.

One participant stated, "Truck drivers need more training to be qualified enough to deal with different types of cargoes. Furthermore, no specific working hours' conditions are applied in Egypt. For example, the drivers are working per trip, not per specified working conditions, as is the case in other countries. Consequently, they may experience sleepiness on long trips, get exposed to substance/drug abuse in order to be able to complete the trip, or have their cargo stolen if they take a nap" P2.

Participant 8 added, "The infrastructures need to be maintained and more services on roads should be added" P8.

Participant 10 stated, "There is the absence of trucks with high specifications, such as safety, security and environmental friendliness" P9.

Additionally, two interviewees pointed out that revolutions and instabilities have a negative impact on the road freight transport sector. This observation emerged from the conducted interviews, further highlighting the multifaceted nature of the challenges faced in the sector: *"the performance of the road freight transport sector nowadays is not quite as efficient as before the 2011 Revolution because some of the neighbouring countries have reduced the amount of cargo exported from Egypt and the quantity of cargoes imported to Egypt. Consequently, some road freight transport companies in Egypt have shut down their businesses as they were unable to run their business or make profit." P10.*

On the other hand, regarding infrastructure maintenance, one of the interviewees contradicts the results of the previous studies, believing that there has been some progress in the infrastructure of road transport in Egypt. They stated: *"... not all the truck drivers are well-trained to deal with the various types of cargoes transported via road or to deal with the risks they may face while transporting cargoes from origin to final destinations, especially when transporting cargoes internationally between two different countries. Also, if there is any type of technology adopted, not all drivers can cope with using it as they prefer to use the common type of trucks ..." P11.*

6.3.2. The Role of Technology Utilisation

The role of technologies in the road freight transport sector has been observed to be lacking in some countries (Miguel et al., 2019). Therefore, road freight transport companies should prioritize increasing their competitiveness through various aspects, including technology adoption, service quality, management, and safety criteria (Besselink et al., 2016). The reluctance to adopt technology stems from the high investment required and the varying levels of technological adaptability among truck drivers (Tobgue et al., 2018; Lindh et al., 2018; Campos et al., 2019). However, it has been suggested that embracing technologies and innovative practices in this sector could help address major issues and improve the performance of road freight transport companies toward sustainability (Li et al., 2017; Nicolaides et al., 2018; Mittal et al., 2018; Anwar et al., 2020).

New international projects are planned to link Egypt with its neighbouring countries, such as the new bridge between Egypt and Saudi Arabia, which is expected to boost trade, economic growth, tourism, and shorten travel time between the two countries (Nosseir, 2016). Egypt's strategic location connects it with neighbouring countries like Sudan, Libya, and the Gulf region via roads (Egypt's Provision Risk Report, 2018). Consequently, some road freight transport companies in Egypt have begun focusing on adopting technological systems, such as eco-driving and tracking systems, and are offering training sessions for truck drivers (Zaki et al., 2019; El-Husseiny et al., 2017).

In light of these observations, it is highly recommended to implement innovative technological solutions to mitigate these impacts, enhance the sector's sustainability, and facilitate information exchange and communication toward achieving sustainability goals (Macharis et al., 2019).

The results from the data collection phases align with those of the previously conducted studies in this field. For instance, one of the respondents confirmed that there is an *"absence of adopting technology in enhancing the road freight transport performance." P1.*

Meanwhile, one of the interviewees highlighted the fact that the Ministry of Egyptian Inland Transport is restructuring the Technology Department to begin adopting technology within the sector, stating: *"... the restructuring of the Technological*

Department in the Ministry of Transport can serve the sector and enhance its performance," P4.

Excessive rules and regulations developed for the road freight transport sector are considered a common problem in some countries (Liimatainen et al., 2013; Atz et al., 2019).

6.3.3. Challenges in adopting Road Freight Transport Performance Measurement Systems

Road freight transport can be significantly improved by effectively managing and measuring performance. This involves recognizing various factors, including an organization's objectives, technology adoption, establishment of rules and regulations, and collaboration between the public and private sectors as well as the government. Currently, there is a lack of a comprehensive and unified system that encompasses different aspects of the road transport industry (Tubis & Wojciechowska, 2017). Consequently, practitioners, academics, government officials, and decision-makers are actively working to address this challenge.

The results indicate a lack of enforcement of rules and regulations within the sector. This alignment between the primary and secondary data is evident. One participant stated: "*the lack of enforcing the rules and regulations for managing the road freight transport sector in Egypt will be the main challenge you will face." FG1.*

Meanwhile, one of the participants from the focus group phase stated, *"the government in Egypt is about to launch new rules and regulations for the road freight transport sector. Therefore, if these rules will be applied accurately and unified for all the Egyptian road freight transport companies, this sector will be enhanced" FG1.*

Fourthly, road freight transport companies, especially those of small to medium size, require operational-level performance measurement to identify and address problems, enhancing performance and achieving sustainability (Noguerol et al., 2018; Havenga & Simpson, 2018).

The road freight transport measurement sector lacks a comprehensive operational-level performance measurement system, with existing systems focusing on specific sustainable aspects and being applied at the city level rather than regionally. Unified performance measurements that serve as Key Performance Indicators (KPIs) for

various road freight transport companies on an operational level, incorporating technology, are missing (UNCTAD, 2017; Curtis., 2013; Franceschini et al., 2019; Tian et al., 2020; Campos et al., 2019; Landstorm et al., 2018). Additionally, freight transport often receives less attention than passenger transport in this sector (Stenico et al., 2019). Road freight transport companies aim to adopt sustainable practices to minimize negative impacts such as pollution and safety concerns that affect public health (Wolff et al., 2018). However, the adoption of a comprehensive performance measurement system, encompassing various aspects of sustainability to enhance cost-effectiveness, remains limited. Consequently, an efficient road freight transport system needs development, including diverse sustainability aspects and regulatory rules. The escalating use of road freight transport has led to negative effects like congestion, pollution, and accidents (Atz et al., 2019; Zgonc et al., 2019).

Based on the data collected in this research, the utilization of performance measurement systems within the road freight transport sector is limited. Some companies resort to alternative indicators, such as financial reports, as highlighted by an interviewee: *"…unfortunately, we don't apply any systems for measuring our performance. However, we measure our performance based on the end of the financial year, whether the company earned profits or not …" P5.*

On the contrary, certain companies assess driver performance through target achievements, accident and crash rates, or the quantity of trips. As an illustration, one respondent stated: *"… the numbers of accidents and crash rates are estimated to identify the performance of drivers on roads and the trucks' performance …" P6.*

Another interviewee mentioned that some of the performance measurement used by their company in measuring its performance are "*Energy Consumption (GPS recorded mileage data, acceleration rate, the mechanical condition of the truck), rush hours, trip delay, trip duration (GPS and journey trip), eco-driving (speed and acceleration) for measuring the driver's performance and random testing for drugs and alcohol, safety through eco-driving and the decreased number of accidents, panic buttons in case of problems, reliability and delay through journey planning and by using tracking software where trips are planned through checkpoints." P11.*

To conclude, the investigation and presentation of results from the literature review and their comparison with findings from other data collection phases reveal a significant degree of consistency. The following sections will emphasize the key commonalities between the literature review and the empirical study:

Firstly, the road freight transport sector demonstrates a deficiency in enforcing rules and regulations, particularly in developing countries. Additionally, the adoption of technologies and innovative practices remains limited among road freight transport companies. Moreover, existing performance measurement systems tend to focus on one or two sustainability aspects, lacking a unified and comprehensive approach to measuring the performance of such companies.

Furthermore, the primary challenges confronting the road freight transport sector encompass congestion, infrastructure maintenance, and driver training (Ambrosino et al., 2019). These issues directly impact the performance of road freight transport companies from a sustainable perspective. It is from this point that the research's originality emerges, and the research aim, questions, and objectives are formulated based on these identified research gaps.

These gaps are as follows: Existing performance measurement systems still exhibit limitations due to their failure to address road freight transport problems from the standpoint of the three sustainable aspects (economic, environmental, and social) (Ambrosino et al., 2019; Atz et al., 2019; Zgonc et al., 2019). There is a paucity of technology adoption and innovative practices with integrated sustainable aspects within a road freight transport performance measurement system (Tian et al., 2020; Campos et al., 2019). Given the high costs associated with most of these solutions, not all road freight transport companies can afford them. Furthermore, the application of predefined performance measurement systems and quantification processes to identify sector-specific problems and improve overall performance is lacking (Tobogu et al., 2018). Integrating a set of performance measurements from sustainable perspectives as Key Performance Indicators (KPIs) to measure road transport companies' performance on an operational level is still underdeveloped (Bedinger et al., 2016; UNCTAD, 2017; Curtis, 2013; Franceschini et al., 2019). The advantages of adopting a predefined performance measurement system on an operational level to quantify remedial actions

and enhance sector performance are yet to be fully realized (Lindh & Rudeke, 2018; Bedinger et al., 2016).

The influence of technologies should be comprehensively captured across each element, specially tailored for this sector, to measure road freight transport companies' operational performance and drive decision-making and problem-solving towards sustainability (Tawfik et al., 2018).

Companies are keen on establishing clear guidelines and criteria for selecting appropriate key performance indicators, encompassing various organizational levels and sustainability aspects in a comprehensive and cohesive manner, while also aligning with their specific objectives (Maestrini et al., 2018; Wiktorsson et al., 2018). Performance measurement and indicators ensure that companies' objectives, processes, and performance are efficiently and effectively executed, provided these companies seek to gain a competitive edge over their rivals (Neely, 2005; Choong, 2013; Saunila, 2018). Nonetheless, the dynamic business environment and the variability in rules and regulations hinder effective utilization. Moreover, uncertainties associated with categorizing, quantifying, and implementing measurement and indicators pose challenges to companies adopting performance measurement systems (Franceschini et al., 2019; Ros et al., 2019; Janic, 2020).

Clearly, the significance of adopting performance measurement systems across diverse industries and companies has been recognized and has experienced substantial growth over the past decades (Neely, 2005).

In summary, this section presents the primary research findings derived from previous studies and establishes a comparison with practical realities. The subsequent section introduces the proposed road freight transport performance measurement framework within the Egyptian context, highlighting disparities between this system and the framework extracted from the literature review.

6.4. The Proposed Road Freight Transport Performance Measurement Framework within the Egyptian Context

The developed road freight transport performance measurement framework, derived from the literature review, has undergone verification, and testing to propose an adapted framework specifically tailored to the Egyptian context, guided by findings from the empirical study. The empirical study has led to certain recommendations aimed at refining the proposed framework to align with the Egyptian market. For instance, participant feedback prompted the inclusion of certain Key Performance Indicators (KPIs) deemed significant within the Egyptian road freight transport context. Conversely, some KPIs were deemed inappropriate for the Egyptian market and thus removed based on participant perspectives.

Drawing from experiences in Malaysia, some participants suggested enhancing driver performance through practical training, particularly addressing the issue of blind spots. A technological solution proposed was the use of special cameras fixed on blind spots to provide drivers with an unobstructed view. Implementing this technological solution in the Egyptian market could improve road visibility for truck drivers.

Another highlighted concern is the inadequate lashing of containers carried by Egyptian truckers, often resulting in containers falling off trucks. The introduction of regulations could ensure proper and secure lashing practices.

Enhanced rules and regulations should be enforced on local businesses to guarantee the safety of their drivers. Additionally, the management of road freight transport requires a regulatory perspective to ensure uniformity, as the absence of clear regulatory guidance has led to inconsistency in performance due to companies operating according to their preferences rather than adhering to structured regulations.

Participants consistently emphasized the pivotal role of road transport in Egyptian logistics, suggesting substantial potential for positive technological impacts. Consequently, incentives from the government should be provided to encourage technology implementation.

Furthermore, participants recommended incorporating risk factors into the proposed road freight transport performance measurement framework to enhance the Egyptian road transport sector. Utilizing an advanced in-monitoring vehicle system (IVMS) to gather reliable data across the three sustainability aspects was highly recommended.

Random toll pricing was highlighted as a significant issue impacting the economic aspect, leading to increased product and trip costs. The scarcity of professional truck drivers and shortcomings in the truck driving license system also necessitate attention and further training.

Moreover, participants broadly concurred that the government's role should be enhanced to mitigate negative environmental impacts, requiring new infrastructure development plans to address the challenges posed by rapid population growth and congestion.

Table 6.2 provides a summary of the KPIs added and removed based on the empirical study, comparing them with the proposed road freight transport performance measurement framework from the literature review, tailored to the Egyptian road freight transport sector. Figure 6.1 visually illustrates the disparities between the proposed road freight transport performance measurement framework derived from the literature review and the adapted framework within the Egyptian context.

Table 6.2 Empirical Study Results regarding the Developed Road Freight Transport Performance Measures Framework

Empirical Study											
Technology utilisation		**Sustainable aspect**									
		Economic				**Environmental**				**Social**	
		Congestion Reduction		**Infrastructure maintenance**		**Congestion reduction**		**Infrastructure maintenance**		**Driver training and qualifications**	
		√		**Partially confirmed**		√		√		√	
Bluetooth measurement system	√	Reliability	√	Accessibility	X	Fuel and energy consumption	√	Energy consumption	√	Safety	√
	√	Mobility	x	Trip delay	√	Noise problem	x	Land use impact	√	Driver crash rates	x
Tracking Journey apps	√	Car crashes	√	Safety problem	X	Traffic jams	√	Noise and air pollution	X	Working hours	√
GPS	√	Operating cost	x	Security level	√	Severe weather	√	Public health	X	Use of controlled substances and alcohol	√
Remote sensing	√	Productivity improvement	√	Trip quality	√	Car exhaust rate	x	Risk management factors	Recommended for the Egyptian context	Driver training	√
Weather forecasting	√	Fuel consumption cost	√	Factory delay	√	Risk management factors	Recommended for the Egyptian context			Driver fatigue	√

Electric vehicles	√	Rush hours	√	Risk management factors	Recommended for the Egyptian context					Exceeding speed limits	x
Eco-driving position	√	Population increase	Recommended for the Egyptian context							Working under pressure & stress	√
Technology initiatives	Recommended for the Egyptian context	Trucking ownership profile	Recommended for the Egyptian context							Sleepiness	√
Tracing and tracking system	√	Poor lashing issues	Recommended for the Egyptian context							Compliance with traffic rules	√
In-monitoring vehicle system IVMS	Recommended for the Egyptian context	Risk management factors	Recommended for the Egyptian context							Blind spot training	Recommended for the Egyptian context
Lack of rules and regulations enforcement	Recommended for the Egyptian context	Random pricing at toll station	Recommended for the Egyptian context							Driver fraud	Recommended for the Egyptian context
										Risk management factors	Recommended for the Egyptian context

N.B.: √= confirmed by the empirical study x= not confirmed by the empirical study partially approved= some confirmed, some not confirmed

New KPIs added= Recommended for the Egyptian context.

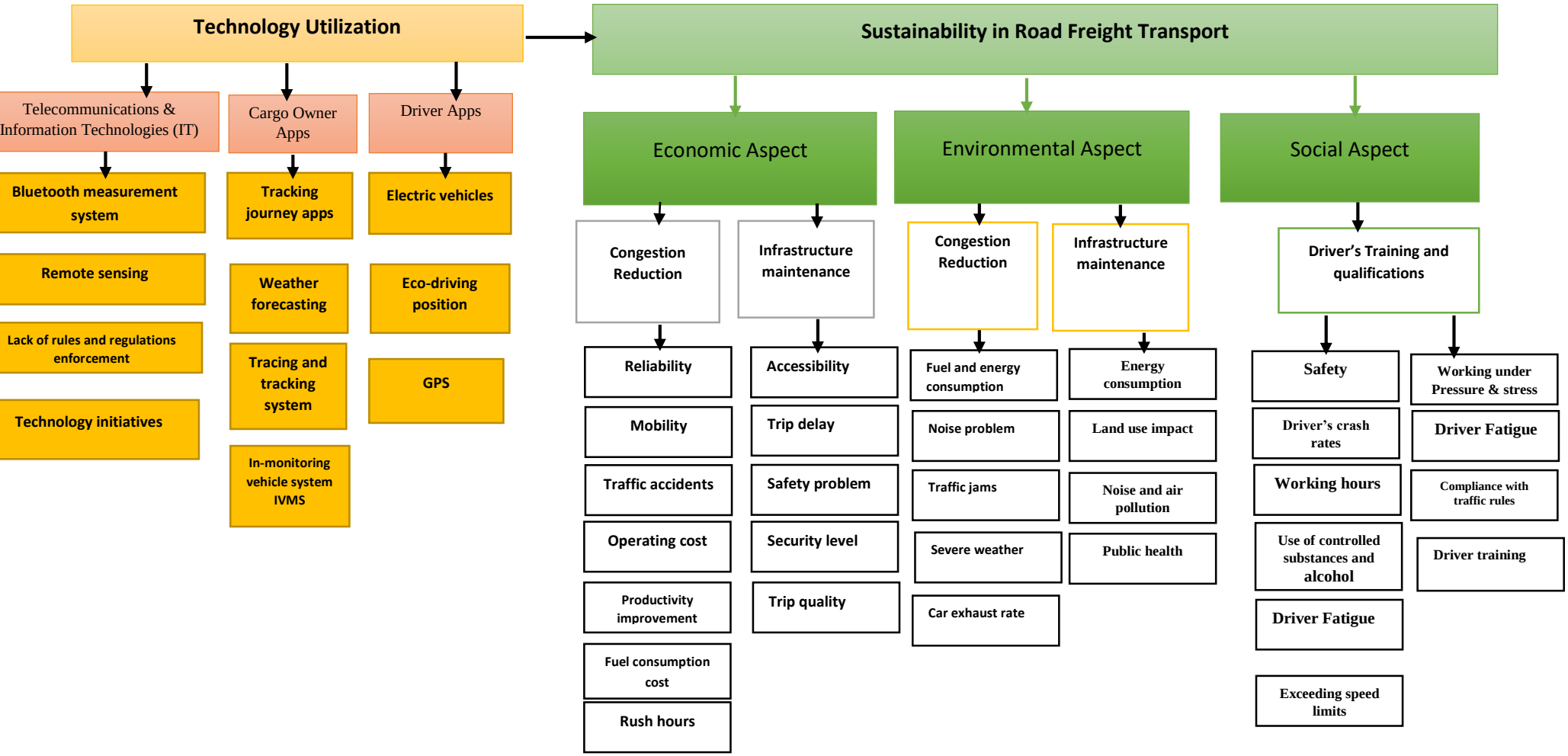


Figure 6.1 The Proposed Road Freight Transport Performance Measurement Framework within the Egyptian Context

6.5. Summary

In this chapter, a comprehensive discussion of the four primary research phases is presented, establishing a direct connection with the research proposition. The aim is to validate the formulated proposition and emphasize its alignment with the executed research phases. The interpretation of research findings follows, illustrating how each research objective and question has been effectively addressed and accomplished across these distinct phases.

The research findings are thoroughly examined, highlighting their interrelation and cohesive contribution to the fulfilment of research questions, objectives, and ultimately the overarching research aim. A systematic comparison is undertaken, probing for any discernible disparities between the outcomes derived from the comprehensive literature review and those synthesized from the various other research phases.

The subsequent chapter delves into the conclusive insights drawn from the entire research endeavour. It encapsulates the achievement of each individual research objective and question, delineates the identified limitations of the study, and proffers further recommendations to enrich this research. Additionally, the chapter underscores the research's noteworthy contribution to both theoretical advancements and practical applications in the field.

CHAPTER SEVEN: CONCLUSIONS AND RECOMMENDATIONS

7.1. Introduction

The road freight transport sector in Egypt holds a pivotal role within the country's economy, serving as a primary conduit for the movement of goods and materials across its expanse. Comprising a multitude of small and medium-sized enterprises, alongside a handful of larger companies, the sector predominantly relies on truck transport for freight, complemented by a lesser portion via rail and a minute fraction through air transportation.

In recent years, the Egyptian road freight transport sector has experienced growth propelled by the nation's burgeoning population and expanding economy. Concurrently, the construction of modern highways and enhanced road infrastructure has bolstered the sector's expansion, amplifying its operational efficiency and velocity.

However, this growth is juxtaposed with challenges, including a dearth of regulatory oversight that engenders safety concerns and heightened expenses. Furthermore, the sector grapples with a scarcity of proficient drivers and a lack of investment in advanced technology and equipment.

To address these challenges, the Egyptian government has instituted strategic measures, spanning increased infrastructure investment and regulatory reinforcement. Furthermore, private sector involvement has been actively promoted to augment efficiency and augment capacity. Within the ambit of this research, an operational-level road freight transport performance measurement framework has been crafted, underscored by the integration of three sustainability dimensions and technological advancement.

This chapter culminates in the presentation of research conclusions, intricately weaving how research objectives and inquiries are met to fulfil the overarching research goal. Additionally, the academic and practical contributions emanating from this research are dissected and analysed. Concomitantly, research constraints are acknowledged, followed by a compendium of recommendations that delineate avenues for future inquiry.

7.2. Research Aim, Objectives, and Questions Fulfilment

The principal aim of this research is to construct a performance measurement framework tailored for road freight transport companies, facilitating performance monitoring, technology integration, and progress toward sustainability.

To realize this overarching goal, four distinct objectives were formulated.

7.2.1. To develop a Theoretical Road Freight Transport Performance Measurement Framework:

The primary research objective focused on highlighting the predominant challenges encountered by the road freight transport sector, given their direct adverse impact on the performance of road freight transport companies. This objective was accomplished through an extensive literature review and analysis of prior studies, aimed at comprehending the sector's principal issues and identifying a set of performance measurements to serve as key performance indicators (KPIs) for gauging the operational performance of diverse road freight transport companies.

The literature review was structured around four key domains: the significance of road freight transport, performance measurement, sustainability, and road freight transport performance measurement systems. This approach culminated in a comprehensive response to the first research question: "What problems does the road freight transport sector face from sustainable perspectives, and how do these issues influence the performance of road freight transport companies?"

The outcome of this research phase revealed a roster of primary challenges confronting the road freight transport sector, encompassing concerns such as congestion, infrastructure maintenance, and driver training and qualifications. Importantly, the investigation underscored the limited availability of road freight transport performance measurement frameworks that holistically integrate the three dimensions of sustainability with technological advancements on an operational level. Furthermore, a gap was identified in the adoption of technologies and innovative practices that address the identified challenges within each facet of sustainability—economic, environmental, and social.

The research findings also illuminated a deficiency in amalgamating technology with a comprehensive array of performance measurements underpinning each sustainable dimension. Such performance measurements ought to be embraced as fundamental metrics for assessing the operational performance of road freight transport companies.

7.2.2. To develop a Conceptual Framework adapted to the Business Context:

This objective is accomplished through a two-phase approach. Firstly, a comprehensive analysis of the global road freight transport sector is conducted, with a specific focus on the Egyptian context, where the empirical study is carried out. In this phase, semi-structured interviews employing Delphi methods are conducted, involving diverse stakeholders such as managers and truck drivers within the road freight transport sector in Egypt. The aim is to thoroughly investigate and evaluate the current situation within this sector.

Consequently, the research question, "How can the adoption of technology contribute to mitigating the challenges faced by the road freight transport sector and promote sustainability?" is systematically addressed. The investigation delves into the ways in which technological applications can offer significant benefits to road freight transport companies. These advantages encompass a spectrum of aspects, including optimized journey planning to navigate roadways and circumvent traffic congestion, precise weather forecasting to reduce accident rates, monitoring acceleration rates for minimizing gas emissions, and assessing land usage impact for effective infrastructure maintenance planning.

By comprehensively exploring the link between the utilization of technological applications, innovative practices, and the three dimensions of sustainability (economic, social, and environmental), specifically within the operational performance of road freight transport companies, an essential research gap is bridged. This achievement is discussed in detail in Chapter Four.

As a result of this investigation, a conceptual framework for measuring the performance of road freight transport within the Egyptian context is developed. Moreover, the Egyptian road freight transport sector is rigorously assessed and meticulously analysed within the parameters of the newly formulated performance measurement framework.

7.2.3. To Test and Verify the Developed Road Freight Transport Performance Measurement Framework by conducting an Empirical Study in Egypt:

To achieve this objective, a comprehensive survey is conducted, involving participants from various sectors of the road freight transportation industry, encompassing both academic experts and industry practitioners. The primary aim of the survey is twofold: first, to validate the developed road freight transport performance measurement framework; and second, to empirically test the relationships that exist between the identified research variables and the research hypotheses.

The research question, "What essential components need to be integrated when devising a performance measurement framework tailored for road freight transport companies?" is meticulously addressed through this survey. The survey outcomes provide a lucid elucidation of the key elements that necessitate inclusion in the process of formulating a performance measurement framework for road freight transport entities.

The culmination of this survey yields a conclusive identification of the core performance metrics that are to be incorporated within the evolved road freight transport performance measurement system. These performance metrics, deemed fundamental as Key Performance Indicators (KPIs), stand poised to be universally employed by diverse road freight transport companies as a means to gauge their performance. Noteworthy components encompassed within these KPIs encompass an array of factors, including but not limited to technology adoption, eco-driving practices, safety proficiency, accident rates, operational expenditures, fuel consumption efficiency, land usage impact, random drug testing compliance, and acceleration rates. These definitive findings are meticulously outlined in Chapter Five.

7.2.4. To Propose a Roadmap for adopting the Applied Road Freight Transport Performance Measurement Framework within the Egyptian Context:

The fourth objective is realized through the facilitation of focus groups, wherein distinct managers representing the selected road freight transport companies contribute to formulating a comprehensive roadmap for the seamless integration and application of the derived road freight transport performance measurement framework within the distinct context of the Egyptian landscape.

Within these focus groups, the specific focus is on the Egyptian road freight transport sector, as insights are garnered to ascertain potential barriers and impediments that may hinder the successful implementation of the meticulously devised road freight transport performance

measurement framework within the operational framework of Egyptian road freight transport entities. Furthermore, the expert input gathered from these focus groups serves as a foundation upon which practical recommendations are constructed, aimed at effectively addressing and mitigating these identified challenges.

As a result, the probing questions "What are the primary obstacles faced by road freight transport companies in the process of adopting the developed road freight transport performance measurement system?" and "What strategies can road freight transport companies employ to surmount these hindrances?" are methodically elucidated through an extensive enumeration of key challenges. These challenges encompass factors such as the deficiency in the enforcement of regulatory norms within the Egyptian road freight transport sector, the inadequate integration of technology, the absence of strategic management planning, unanticipated crises, antiquated trucking infrastructure, and the scarcity of proficient drivers.

Mitigating strategies are also thoughtfully suggested to alleviate these roadblocks. Among these proposed actions are enhanced collaboration between the government and private sector, with a specific focus on driver training programs, facilitation and support for technology adoption, standardization of regulatory protocols, sectoral restructuring initiatives, toll establishment measures, and concerted efforts to reshape the prevailing driver culture. Moreover, it is recommended that road freight transport companies themselves play an active role by implementing transformative measures aimed at altering customer perspectives to prioritize trip quality over cost considerations, embracing performance measurement systems for performance evaluation, and formalizing company registration processes. A comprehensive delineation of these actions is elaborated in Chapter Five.

This section robustly underscores the successful validation and realization of the research objectives and inquiries through the adept employment of the research methodology. In tandem, the attainment of the overarching research aim is clearly demonstrated and substantiated (refer to Table 7.1). In the ensuing section, the distinct contributions of this research, both within the academic realm and practical sphere, are thoughtfully expounded upon.

Table 7.1 Research Aim, Objectives, and Questions Fulfilment

Number	Research Objectives	Research Questions	Research phase fulfilment
1	To develop a theoretical road freight transport performance measurement framework extracted from the literature review	What are the problems facing the road freight transport sector from sustainable perspectives and impacting the performance of road freight transport companies?	✓ Fulfilled through conducting literature review (1st phase) and semi-structured interviews (2nd phase)
2	To develop a conceptual framework adapted to the business context	To what extent can technology assist in mitigating the problems facing the road freight transport sector to achieve sustainability?	
3	To test and verify the developed road freight transport performance measurement framework through conducting an empirical study in Egypt	What key elements need to be incorporated when developing a performance measurement system for a road freight transport company?	✓ Fulfilled through conducting surveys (3rd phase)
4	To propose a roadmap for adopting the applied road freight transport performance measurement framework within the Egyptian context	What are the possible challenges facing road freight transport companies when adopting the developed road freight transport performance measurement framework? How could road freight transport companies overcome these obstacles?	✓ Fulfilled through conducting focus groups in the Egyptian road freight transport companies (4th phase)
Research aim is achieved and fulfilled by clearly answering the four main research questions and conducting the four research phases to fulfil the research objectives.			

7.3. Research Contributions

In this section, the theoretical and practical contributions of this research are presented.

7.3.1. Theoretical Contributions

This research makes an original contribution to the theory of road freight transport performance measurement by addressing the existing limitations in the available frameworks. It identifies that there are limited performance measurement frameworks that fully incorporate the three sustainable aspects while using technology. As a response to this gap, the study proposes the development of a bespoke performance measurement framework specific to the

road freight transport sector. Firstly, the proposed Performance Measurement System is underpinned by a comprehensive framework covering various aspects of sustainability, tailored specifically for road freight transport companies. Within this framework, a set of performance measurements is developed, serving as Key Performance Indicators alongside technological advancements. The aim is to assist road freight transport companies in measuring their operational performance, identifying areas that require technological improvement, and ultimately enhancing their decision-making towards sustainable development. The research builds on a review of previous studies on road freight transport performance measurement, highlighting the identified problems facing the sector from different sustainable perspectives. The significance of quantifying actions in road freight transport companies is emphasised, and the measurement of operational performance is thoroughly discussed. The proposed road freight transport performance measurement framework is designed to assess companies' operational performance and provide aggregated results as feedback for decision-makers, enabling them to improve future business strategies. Moreover, the study identifies a lack of existing performance measurement frameworks that fully integrate the three sustainable aspects, particularly with technological practices embedded in each element. In response, the proposed performance measurement framework incorporates various sustainable problems, technological changes, and a set of performance measures to be used as KPIs for different road freight transport companies. This research significantly contributes to knowledge by offering a comprehensive road freight transport performance measurement framework that addresses sustainability challenges from economic, environmental, and social perspectives. It also analyses and assesses the road freight transport industry to identify global sector challenges and propose solutions for adopting the developed performance measurement framework in various countries and contexts.

Secondly, this research contributes methodologically by adopting mixed research methods to verify and test relationships between research variables. The research phases, presented in chapter three, incorporate various research methods to answer research questions, achieve research objectives, and validate the developed road freight transport performance measurement framework. The first phase involves a literature review, examining road freight transport, performance measurement systems, and sustainability in the sector. It highlights the research gap, leading to the development of research questions, proposition, hypotheses, and aim. In the second phase, semi-structured interviews are conducted using the Delphi method to deeply analyse the road freight transport sector, identify main problems, and explore the

role of adopting technologies and performance measurement for sector enhancement. The third phase involves surveys to test the relationships between identified research variables. Finally, the fourth phase consists of focus groups to develop a roadmap for implementing the proposed road freight transport performance measurement framework. This comprehensive approach effectively addresses research questions, fulfils research objectives, and ensures research validity and reliability.

Thirdly, this research extends the limited studies on the adoption of technologies and innovative practices incorporated with different performance measurements and their impacts on reducing road freight transport problems from a sustainable perspective.

Through an extensive literature review and semi-structured interviews using the Delphi method, the research underscores the importance of adopting technologies in enhancing the road freight transport sector's performance. Subsequently, a survey is designed to test the degree of positive relationships between technology adoption and performance enhancement in the road freight transport sector towards sustainability. This expansion of knowledge sheds light on the significance of incorporating technology and innovative practices to address sustainability challenges in the industry.

7.3.2. Practical Contributions

Different research phases to be followed are proposed in order to apply the developed performance measurement framework in different countries with different contexts as the developed framework includes different KPIs that can be incorporated according to the size and operation of each company (see Table 7.2).

The developed road freight transport performance measurement framework will help the road freight transport managers and decision-makers to measure their companies' performance by incorporating the performance measurement as KPIs and to identify the problems they face to propose sustainable solutions. Each road freight transport company would select the performance measurement from each category they require for measuring their performance according to their size and operations.

Moreover, road freight transport companies should be capable of tracing the impact of technologies in each single activity, in addition to identifying the drivers in need of more improvement.

Second, this thesis contributes to practice by proposing a roadmap to overcome the obstacles and challenges that might stand against adopting the proposed framework within the Egyptian context. By suggesting different solutions to overcome these obstacles, the road freight transport sector would be able to adopt the proposed framework in order to measure and track its performance from an operational level (see Table 7.2).

An empirical study has been conducted in one of the developing countries which lack the adoption of technologies with performance measurement to reach sustainability in the road freight transport sector. Suggested solutions to overcome the obstacles of adopting road freight transport performance measurement framework include government cooperation with road freight transport companies to restructure the entire sector in Egypt, to enforce and unify the rules and regulations used to manage it, to maintain the road infrastructure to facilitate the adoption of innovative solutions, and to invest in better train drivers to deal with new, innovative vehicles. Customers can help enterprises adopt performance measurement framework by emphasising trip quality above trip cost to encourage road freight transport companies to spend more on technological apps and performance measurement framework. Road freight transport companies should focus more on adopting and utilising technologies to enhance trip quality. Also, the road freight transport companies would measure their performances from an operational level to track problems and area of improvement to reach sustainability. Figure 7.1 illustrates the role of the main road freight transport stakeholders:

- Trucking companies and drivers, who operate the vehicles and provide the transportation services.
- Government agencies, such as the Department of Transportation and state transportation departments, which regulate and oversee the trucking industry.
- Customers or end users, who benefit from the delivery of goods via truck transportation.

It is worth mentioning that in addition to these stakeholders, other stakeholders are also considered in the road freight transport sector which are:

- Shippers and receivers, who are the businesses or organizations that send and receive goods via truck transportation.
- Insurance companies, which provide coverage for trucking companies and drivers.

- Equipment manufacturers, who produce and supply the trucks and other equipment used in the industry.
- Fuel providers, who supply the fuel needed to operate the trucks.
- Maintenance and repair companies, who service and maintain the trucks.
- Logistics companies, who coordinate and manage the movement of goods.
- Unions and trade associations, which represent the interests of trucking companies and drivers.

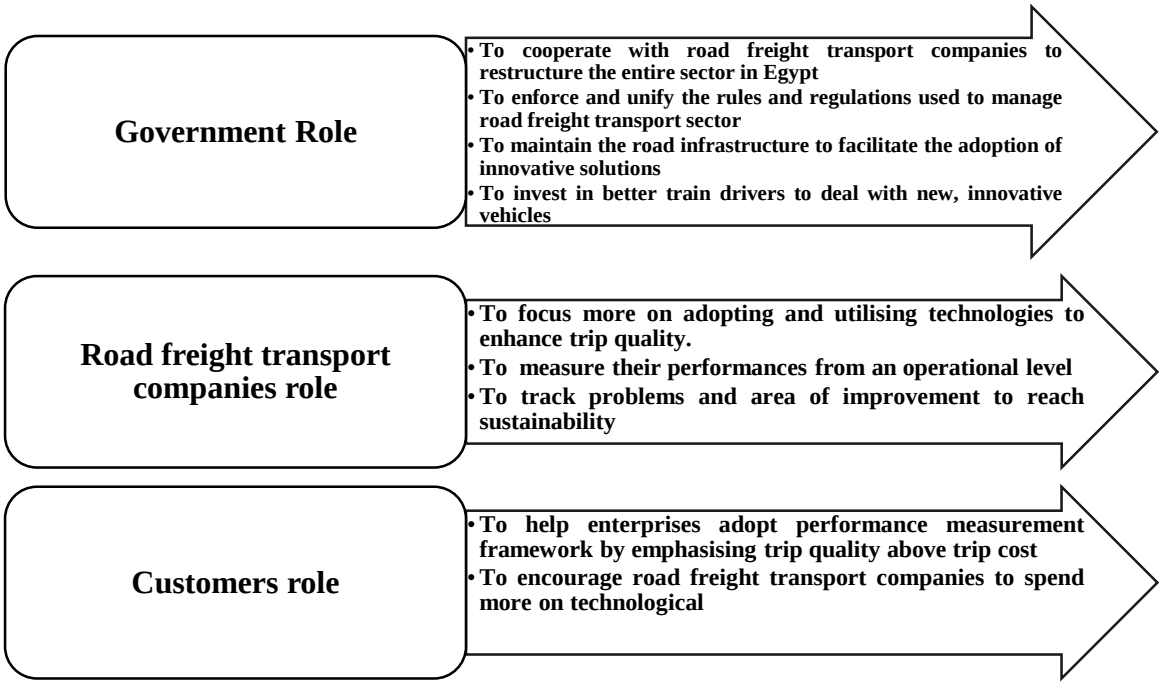


Figure 7.1 The Role of the Main Road Freight Transport Stakeholders

Therefore, the evolved road freight transport performance measurement framework should be self-contained, devoid of any necessity to integrate into pre-existing performance measurement frameworks. This is due to its inherent integration of the triad of sustainable aspects, seamlessly interwoven with technological applications. A succinct overview of the principal accomplishments in terms of research contributions is encapsulated in Table 7.2.

Table 7.2 Research Contributions Achievement

Research Contribution	Phase	Chapter
Some performance measurement obtained by developing a theoretical road freight transport performance measurement framework	Analysing previous studies in the field of road freight transport, performance measurement, sustainability, and sustainable road freight transport performance measurement system Identifying the existing performance measurement system, identifying the main problems facing this sector from the sustainable perspective	Chapter Two: Literature Review
Different methodological approaches adopted in this research to test and identify the relationships between the research variables	In order to fulfil the research aim, proposition objectives and questions	Chapter Three: Research Methodology
Conceptual road freight transport performance measurement framework development Different phases and procedures to be proposed in order to apply the developed performance measurement framework in different countries with different contexts	Analysing and assessing the current situation of the road freight transport industry worldwide and especially in Egypt Performance measurement to be incorporated as KPIs to measurement different road freight transport companies with different sizes and operations (Delphi method)	Chapter Four: Analysing the Road Freight Transport Sector in Egypt, Delphi Analysis
Various elements identified for improving road freight transport companies from a technological perspective so as to enhance decisions toward sustainable development. Proposing a roadmap for adopting the developed road freight transport performance measurement framework	Testing the relationship between the identified variables incorporated in the developed PMS. Proposing solutions for adopting the developed road freight transport performance measurement framework within the Egyptian context	Chapter Five: Empirical Study on the Egyptian Road Freight Transport Companies

The justification behind the proposed road freight transport performance measurement framework is meticulously tested and confirmed. This measurement framework serves as a pivotal tool to empower diverse road freight transport companies to gauge their operational performances with a keen focus on granularity. Through this approach, these companies are equipped to pinpoint areas that warrant enhancements, thereby fostering informed decision-making that steers them towards the realm of sustainability (as illustrated in Figure 6.1). By fortifying the operational facets, an eventual cascade effect ensues, potentially influencing strategic outcomes. A prime instance of this ripple effect is the potential reduction in pollution levels, which, in turn, contributes to the amelioration of public health conditions.

7.4. Research Limitations

In this section, the limitations of this research will be presented and highlighted. The first limitation is the limited availability of established frameworks constrained the access to relevant literature and data for the formulation of the proposed road freight performance measurement framework.

Another limitation that arose during data collection was the exclusive focus of the semi-structured interviews (Delphi 1st round) and empirical study on the road freight transport sector in Egypt. This narrow scope may hinder the generalizability of the findings to other countries or regions with different levels of technological penetration in the road freight sector. Variations in infrastructure development, topography, culture, and regulatory environments in other developing countries could significantly impact the results, rendering them less applicable in a broader context.

Furthermore, it is important to recognise that the Delphi method, while valuable for developing the conceptual performance measurement framework and investigating the current situation of the road freight transport sector in Egypt, has its limitations. The potential for bias and the level of consensus among the participating experts may influence the outcomes of the Delphi process.

Additionally, though the response rate of 95 out of 200 targeted participants in the surveys was deemed acceptable, the exclusion of responses from some participants may have limited the comprehensiveness and depth of insights gained from the study. A higher response rate with the participation of all targeted participants could have enhanced the research's overall robustness and accuracy in drawing conclusions.

The conducted regression analysis focused on the core variables within the established framework for road freight transport performance measures. However, the potential inclusion of additional variables from this framework in the regression analysis could have provided a more comprehensive and in-depth exploration, yielding more detailed outcomes and enhanced analysis.

COVID-19 limitations restricted the number of focus groups conducted in three road freight transport companies. The researcher originally intended to conduct more focus groups, including an integrated one with all participating companies, to gather deeper insights and opinions enriching the recommended roadmap for adopting the proposed road freight transport performance measurement framework across various companies.

Due to time constraints, the empirical study was limited to the Egyptian road freight transport sector. As a result, the researcher could not conduct empirical studies in other countries to perform a comparative analysis and showcase differences between the results. Furthermore, a case study exploring the impact of adopting the proposed performance measurement framework on a specific road freight transport company was also not feasible.

7.5. Recommendations for Further Research Work

Addressing the research limitations identified earlier, several recommendations are put forward for future work.

Enhance the performance measurement framework by incorporating additional variables, such as resilience, other technological applications, and unique challenges faced by road freight transport in specific contexts, such as global pandemics and land-locked countries. This expanded framework can provide valuable insights and testing opportunities for operational resilience in road freight transport companies, aiding managers in identifying areas for improvement and informed decision-making to enhance sustainability and overall company performance.

Consider employing a different methodological approach to evaluate the application of the developed performance measurement framework. Implementing before-and-after scenarios can provide a deeper understanding of the framework's effectiveness and impact.

Collect data from other developing countries to conduct a comparative analysis, highlighting differences between data collected and recommendations for enhancing the road freight transport sector. Focusing on aspects of resilience and agility can offer diverse perspectives on the proposed performance measurement framework.

In conclusion, this research addresses critical aspects of road freight transport, exploring problems, risks, challenges, technological innovations, and performance measurement in the Egyptian context. The development of a road freight transport performance measurement framework contributes to both academic knowledge and practical applications. Recommendations for further research aim to overcome the limitations encountered in this study and encourage future researchers to delve deeper into the field of road freight transport.

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APPENDICES

Appendix One: Semi-Structured Interview Protocol

Title

Investigating and identifying the problems and challenges facing the road freight transport companies in Egypt.

Purpose

- To investigate the challenges and problems facing the road freight transport companies and how they manage and control them.
- To explore the role of adopting technological apps and innovative solutions in limiting the impact of the problems the companies face.
- To discover the existing performance measurement systems used by the road freight transport companies in measuring their companies' performance.

Participants

The interview will be conducted with:

- Top managers
- Operations managers
- Financial managers
- Human Resources (HR) managers
- Quality managers
- Drivers

Procedures

Semi-structured interviews will be conducted to focus deeply on the gathered data.

The interview will be conducted with a number of companies in the field to test the quality of the questions and the developed framework, and then it will be conducted after reviewing the questions and framework with a wider range of companies to validate the developed road freight transport performance measurement system (1st round of Delphi).

The upcoming section presents the questions which will be asked in order.

I would like to thank you for sharing some of your time to meet me today.

I am Sohaila Hassan Elgazar and I am looking forward to hearing from you about your experience and knowledge in the road freight transport field which will assist me in collecting the needed data for my research in developing a performance measurement system to enhance the performance of road freight transport companies through the lens of sustainability.

The interview will take approximately an hour. I will tape-record it to avoid missing any of your comments if you agree to have this interview with me.

All your answers and responses to the questions will be kept confidential and it will only be shared for research purposes. Moreover, I will make sure that all the information included in the research does not identify you as a respondent.

Also, you have the right to end the interview at any time and to refuse responding to any of the questions.

Are there any questions regarding what I have just mentioned? Are you willing to participate in this interview?

1. **'Based on previous conducted studies, it was observed that congestion, infrastructure maintenance and drivers' qualifications are the main dimensions affecting road freight transport through the lens of sustainability (economic, environmental and social)'. To what extent do you agree with this statement? Are there any further dimensions that should be added under each aspect of sustainability? Why?**
2. **Technological aids are good tools for diminishing these problems. To what extent do you agree with this statement? Why?**
3. **How does a road freight transport company measure its performance?**

Thank you for your participation.

Driver's Interview Questions:

10. **How long have you been working as a professional truck driver?**
11. **'The driver has to complete a certain type of training according to the type of freight he is responsible for transporting'. To what extent to do you agree with this statement? Why?**
12. **From your point of view, do you deliver the safety needed while driving the truck?**
13. **In case accidents occur, how do you deal with them?**
14. **What external factors increase your stress level? Let them tell you, and if they do not understand the question, give them examples, such as weather, congestion, etc.**
15. **Does your company apply the safety regulation rules and the maximum number of working hours?**
16. **How often are you subject to drug and alcohol tests? (Once a year, a month, etc.)**
17. **Are you well trained in the use of all the new technology adopted in freight trucks and the digital signs?**
18. **Do you wish to provide me with further information?**

Thank you.

Appendix Two: Focus Groups Protocol

Title

Demonstrating the applicability of the developed road freight transport performance measurement system in road freight transport companies and identifying the obstacles standing against its application.

Purpose

- To present the developed road freight transport performance measurement system through the lens of sustainability in order to demonstrate its applicability in road freight transport companies and to gain feedback regarding the extent to which this system could assist decision-makers in identifying problems to enhance performance and achieve sustainability.
- To investigate the challenges and obstacles facing road freight transport companies to apply the developed road freight transport performance measurement system and how to manage and control them.

Participants

The interview will be conducted with:

- Quality manager
- Logistics and transport manager
- Operations manager
- Financial manager
- Professional driver

Procedures

The focus groups will be conducted with participants from Egyptian road freight transport companies.

The focus groups will be conducted with a number of companies in the field to test the quality of the questions and the developed framework, and then they will be conducted after reviewing questions and framework with a wider range of companies to validate the developed framework.

The upcoming section presents the questions which will be asked in order.

I would like to thank you for sharing some of your time with me to meet you today.

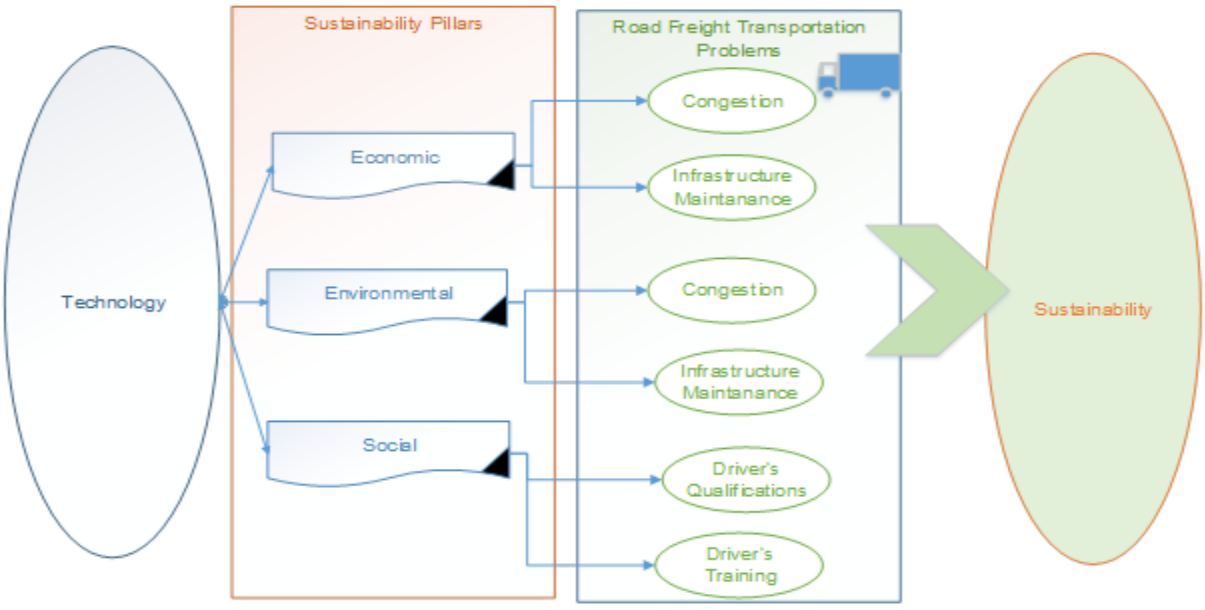
I am Sohaila Hassan El-Gazar (Elgazar?) and I am looking forward to hearing from you about your experience and knowledge in the road freight transport field, which will assist me in collecting the needed data for my research in developing a performance measurement system to enhance the performance of road freight transport companies through the lens of sustainability.

The interview will take approximately an hour. I will tape-record it to avoid missing any of your comments if you agree to have this interview with me.

All answers and responses to the questions will be kept confidential and they will only be shared for research purposes. Moreover, I will make sure that all the information included in the research does not identify you as a respondent.

Also, you have the right to end the interview at any time and to refuse responding to any of the questions.

Are there any questions regarding what I have just mentioned? Are you willing to participate in this interview?



Road freight transport system through the lens of sustainability

Source: Elgazar, S., Tipi, N., Njoya, E, 2019

The upcoming section presents the performance measurement used under each dimension to measure it.

1. **Technology is the umbrella serving the three aspects of sustainability and impacting the performance of road freight transport companies**.
   - Telecommunications and Information Technologies (IT), such as mobile phone applications for managing road freight transport, and their effects on simplifying the movement of cargoes;
   - Intelligent Transportation System (ITS), such as smarter vehicles, highways monitoring systems and new systems like alternate fuels and vehicles for ground transportation;
   - Navigation and tracing systems;
   - Cargo owners applications for simplifying procedures;
   - Driver's applications for facilitating the trucks' movement and managing the way used.

Economic aspect:

1. Congestion problem

KPIs:

Safety problem, Operating cost, Productivity improvement, Fuel cost, Fuel consumption, Rush hours, Reliability, Flexibility, Mobility, Land blockage, and Car crashes.

2. Infrastructure maintenance

KPIs:

Accessibility, Trip delay, Mobility, Trip quality, Safety, Security level, Transit time, Factory delay, and trip duration.

Social Aspect

3. Driver's training and qualifications

KPIs:

Working hours, Driver's crash rates, Safety, Driver's training, Use of controlled substances and alcohol, Driver's fatigue, Exceeding speed limits, Working under pressure and stress, Sleepiness, and Compliance with traffic rules.

Environmental Aspect

4. Congestion problems

KPIs:

Fuel and energy consumptions, noise problem, traffic jams, severe weather, and car exhaust rate.

5. Infrastructure maintenance

KPIs:

Green transport, energy consumption, land use impact, noise and air pollution, and public health.

Q1: According to previous conducted studies and the road freight transport industry analysis, a performance measurement system has been developed to investigate the impact of measuring road freight transport on improving the road freight transport companies' performance through the aspects of sustainability. From your own point of view, how can this performance measurement system assist in measuring companies' performance?

Q2: From your experience in the road freight transport industry, what are the challenges and obstacles which can stand against applying the developed road freight transport framework?

Q3: Based on your answers to question 2, how can these challenges and obstacles be overcome?

Q4: From your own point of view, is there any further information you wish to add? If any, please mention them.

Thank you for your participation.

Appendix Three: Survey Protocol and Invitation Letter

Title

Validating the developed road freight transport performance measurement system

Purpose

- To present the developed road freight transport performance measurement system through the lens of sustainability so as to validate it through gathering participants' points of view.

Participants

The survey will be conducted with:

- Participants (practitioners and academics) in the field of road freight transport.

Procedures

The survey will be conducted with a number of participants in the field to test the quality of the questions and the developed road freight transport performance measurement system, then it will be conducted after reviewing the questions and the developed road freight transport performance measurement system with a wider range of participants to validate the developed road freight transport performance measurement system.

The upcoming section presents the questions which will be asked in order.

First E-mail/Invitation Sent to Participants

Dear Sir/Madam,

I am sending you this email to invite you to participate in my online study on the road freight transport industry.

Brief Explanation:

I am a Doctoral (Ph.D.) candidate at Huddersfield University, and my topic is:

Developing a performance measurement system for freight road transport companies through the lens of sustainability: An empirical study on the Egyptian freight road transport companies.

Accordingly, I am keen on having participants' insights from all over the world by filling out the following survey.

Research overview:

1. The survey is used and utilized in my research for collecting data anonymously and over the internet. Therefore, I hope to gain participants' insights as my research aims specifically at getting information from participants.
2. An expert is someone that has great and deep experience and knowledge in the road freight transport field.
3. A road freight transport performance measurement system has been developed through the lens of sustainability. Accordingly, I am strongly in need of your experience in the field and your point of view regarding the proposed road freight transport performance measurement system.

This project will take an hour to complete for each round over a one-month period.

There is a set of online surveys to fill. The study should start a few days after your participation consent.

This study is completely voluntary and confidential. If you are unable to participate, please feel welcomed to let me know, and you will not be contacted further. I will keep your decision to participate, not to participate, or to discontinue the study entirely confidential as well.

If you are willing to participate, I need to let you know the following confidentiality guidelines of the study, as determined by Huddersfield University and myself.

1. All information will be provided over the Internet. Since it is possible that information provided over the Internet may be viewed by individuals who are not on my research team, I will use a secure website for the study questions.
2. I will use a study number, and not your name, to identify your responses. I will not collect your name or use any identifying information about you in the online study.

3. All the data gathered from you will be kept in password-secured computer files.
4. After the study is accomplished, I will also ask if you would like your name to be included as part of the expert panel. These would be the only times your name would be identified as a participant.

If you have any questions about the research study itself, please contact me at Sohaila.Elgazar@hud.ac.uk. I would highly appreciate it if you were able to participate in my research. Thanking you very much for your consideration of my study. I am looking forward to learning more about your expertise.

Sincerely,

Sohaila El-Gazar

Ph.D. candidate at Huddersfield University

Developing a Performance Measurement System for Road Freight Transport Companies through the Lens of Sustainability: An Empirical Study on the Egyptian Road Freight Transport Companies

The reliance on road transport in transporting freight has increased dramatically. Therefore, the number of road freight transport companies has risen and their performance improved. However, road freight transport companies face various problems in managing, measuring their performance and transporting various types of cargoes. Furthermore, it has been realized that transporting cargoes via road has led to negative consequences that have environmental, economic, and social impacts. Recently, researchers have recommended that adopting technology in road freight transport companies should assist in reducing these negative impacts, but there has still been a lack in using road freight transport applications that can help in solving the problems faced by road freight transport companies and in enhancing their performance, especially in Africa. Based on the previous studies conducted in this area, there are various performance measurement systems that exist, but there are no road freight transport systems adopted through the lens of the three aspects (economic, environmental, and social) of sustainability and that consider technology as a main aspect serving them. Hence, this research aims at developing a road freight transport system through the lens of sustainability considering technology as a main aspect serving it. This research is comprised of three main phases as follows:

1. The first phase of this research is to develop a conceptual road freight transport framework based on previous conducted studies in this area and the analysis of the road freight transport industry. The conceptual framework is comprised of the three main sustainable aspects; economic, environmental, and social; and the main dimensions under each aspect are: for the economic (congestion problems and infrastructure maintenance), environmental (congestion problems and infrastructure maintenance), and social (drivers' training and qualifications). Technology is considered as a main aspect serving the aforementioned dimensions. Also, there are identified key performance indicators (KPIs) for each dimension to be able to measure it.

2. The second phase of this research is to investigate and test the developed road freight transport performance measurement system by conducting semi-structured interviews (Delphi method).

3. The third phase of this research is to confirm the results of the semi-structured interviews analysis and validate the developed road freight transport performance measurement system by conducting a survey.

4. The fourth phase of this research is to demonstrate the applicability of the developed road freight transport system by conducting focus groups with the Egyptian road freight transport companies. In this survey, the researcher needs participants' opinions on each dimension and KPIs under each aspect whether those are relevant or not to the road freight transport industry. Also, one can feel free to add more information or points of view that support and add more value to the developed framework.

N.B. Although the environmental and economic aspects include the same dimensions, different KPIs are used to measure them.

Sustainability: is the ability to maintain at a certain level.

Dimension: is the feature of a certain situation.

Key Performance Indicators (KPIs): are measurable values that demonstrate how effectively a company is doing.

Thank you for your participation.

*Required

1. Email address *

Personal Information

2. Date of Birth *

Example: 15 December 2012

3. Age *

4. Gender * Mark only one oval.
   - Female
   - Male
   - Prefer not to say
   - Other:

5. Nationality *

6. Position/title *

7. Work Experience *

8. Educational level * Mark only one oval.
   - Bachelor's degree
   - Master's degree
   - Doctoral Degree

9. Study area *

Economic Aspect:
Please fill in whether you agree, disagree or are not sure about the following road freight transport problems.

N.B. A=Agree, DA=Disagree, NS=Not Sure.

10. 1. Does congestion affect the road freight transport performance from an economic perspective? * Mark only one oval.

- Yes
- No
- Maybe

If yes, please pick the KPIs which can be used to measure this dimension from the following list, from questions a to g.

---

11. a. Reliability *

Mark only one oval.

- Agree
- Disagree
- Not sure

12. b. Mobility *

Mark only one oval.

- Agree
- Disagree
- Not sure

13. c. Car crashes *

Mark only one oval.

- Agree
- Disagree
- Not sure

14. d. Operating cost * Mark only one oval.

- Agree
- Disagree
- Not sure

15. e. Productivity improvement * Mark only one oval.

- Agree
- Disagree Not
- sure

16. f. Fuel consumption and cost * Mark only one oval.

- Agree
- Disagree
- Not sure

17. g. Rush hours *
Mark only one oval.

- Agree
- Disagree
- Not Sure

18. 2. Does infrastructure maintenance affect the road freight transport performance from an economic perspective? * Mark only one oval.

- Yes
- No
- Maybe

If yes, please pick the KPIs which can be used to measure this dimension from the following list, from questions a to f.

---

19. a. Accessibility *
Mark only one oval.

- Agree
- Disagree
- Not sure

20. b. Trip delay *
Mark only one oval.

- Agree
- Disagree
- Not sure

21. c. Safety problem * Mark only one oval.

- Agree
- Disagree
- Not sure

22. d. Security level *

Mark only one oval.

- Agree
- Disagree
- Not sure

23. e. Trip quality *

Mark only one oval.

- Agree
- Disagree
- Not sure

24. f. Factory delay *

Mark only one oval.

- Agree
- Disagree
- Not sure

Social Aspect:

Please fill in whether you agree, disagree or are not sure about the following road freight transport problems.

N.B. A=Agree, DA=Disagree, NS=Not Sure.

25. 1. Based on the previous conducted studies on road transport, it has been noticed that drivers' qualifications and training play an important role in enhancing or reducing the road freight transport performance. To what extent do you agree with this statement? *

Mark only one oval.

- Yes
- No
- Maybe

If yes, please pick the KPIs which can be used to measure this dimension from the following list, from questions a to j.

---

26. a. Working hours * Mark only one oval.

- Agree
- Disagree
- Not sure

27. b. Driver's crash rates * Mark only one oval.

- Agree
- Disagree
- Not sure

28. c. Safety *

Mark only one oval.

- Agree
- Disagree
- Not sure

29. d. Driving training * Mark only one oval.

- Agree
- Disagree
- Not sure

30. e. Use of controlled substances and alcohol * Mark only one oval.

- Agree
- Disagree
- Not sure

31. f. Driver's fatigue * Mark only one oval.

- Agree
- Disagree
- No sure

32. g. Exceeding speed limits * Mark only one oval.

- Agree
- Disagree
- Not Sure

33. h. Working under pressure & stress * Mark only one oval.

- Agree
- Disagree
- Not sure

34. i. Sleepiness *
Mark only one oval.

- Agree
- Disagree
- Not sure

35. j. Compliance with traffic rules * Mark only one oval.

- Agree
- Disagree
- Not sure

Environmental Aspect:
Please fill in whether you agree, disagree or are not sure about the following road freight transport problems.
N.B. A=Agree, DA=Disagree, NS=Not Sure.

36. 1. One of the main aspects of sustainability is the environmental aspect, accordingly companies are looking forward to achieving it. Does congestion have a direct effect on a company's performance from an environmental point of view? * Mark only one oval.

- Yes
- No
- Maybe

If yes, please pick the KPIs which can be used to measure this dimension from the following list, from questions a to e.

---

37. a. Fuel and Energy Consumption * Mark only one oval.

- Agree
- Disagree
- Not sure

38. b. Noise Problem * Mark only one oval.

- Agree
- Disagree
- Not sure

39. c. Traffic Jams *
Mark only one oval.

- Agree
- Disagree
- Not sure

40. d. Severe weather * Mark only one oval.

- Agree
- Disagree
- Not sure

41. e. Car Exhaust Rate * Mark only one oval.

- Agree
- Disagree
- Not sure

42. 2. Does road infrastructure maintenance have a direct effect on a company's performance from an environmental point of view? * Mark only one oval.

- Yes
- No
- Maybe

If yes, please pick the KPIs which can be used to measure this dimension from the following list, from questions a to d.

---

43. a. Energy Consumption * Mark only one oval.

- Agree
- Disagree
- Not sure

44. b. Land use impact * Mark only one oval.

- Agree
- Disagree
- Not sure

45. c. Noise and air pollution * Mark only one oval.

- Agree
- Disagree
- Not sure

46. d. Public health *
Mark only one oval.

- Agree
- Disagree
- Not sure

Technology
N.B. A=Agree, DA=Disagree, NS=Not Sure.

47. 1. Technology is the umbrella serving the three aspects of sustainability and impacting the performance of road freight transport companies. * Mark only one oval.

- Yes
- No
- Maybe

If yes, which of the applications from the mentioned list can be used to assist in enhancing performance?

---

48. a. Telecommunications and Information Technologies (IT), such as mobile phone applications, for managing road freight transport and their effects on facilitating the movement of cargoes; * Mark only one oval.

- Agree
- Disagree
- Not sure

49. b. Intelligent Transportation Systems (ITS), such as smarter vehicles, highways monitoring systems and new systems, like alternate fuels and vehicles for ground transportation * Mark only one oval.

- Agree
- Disagree
- Not sure

50. c. Cargo Owners applications for simplifying procedures * Mark only one oval.

- Agree
- Disagree
- Not sure

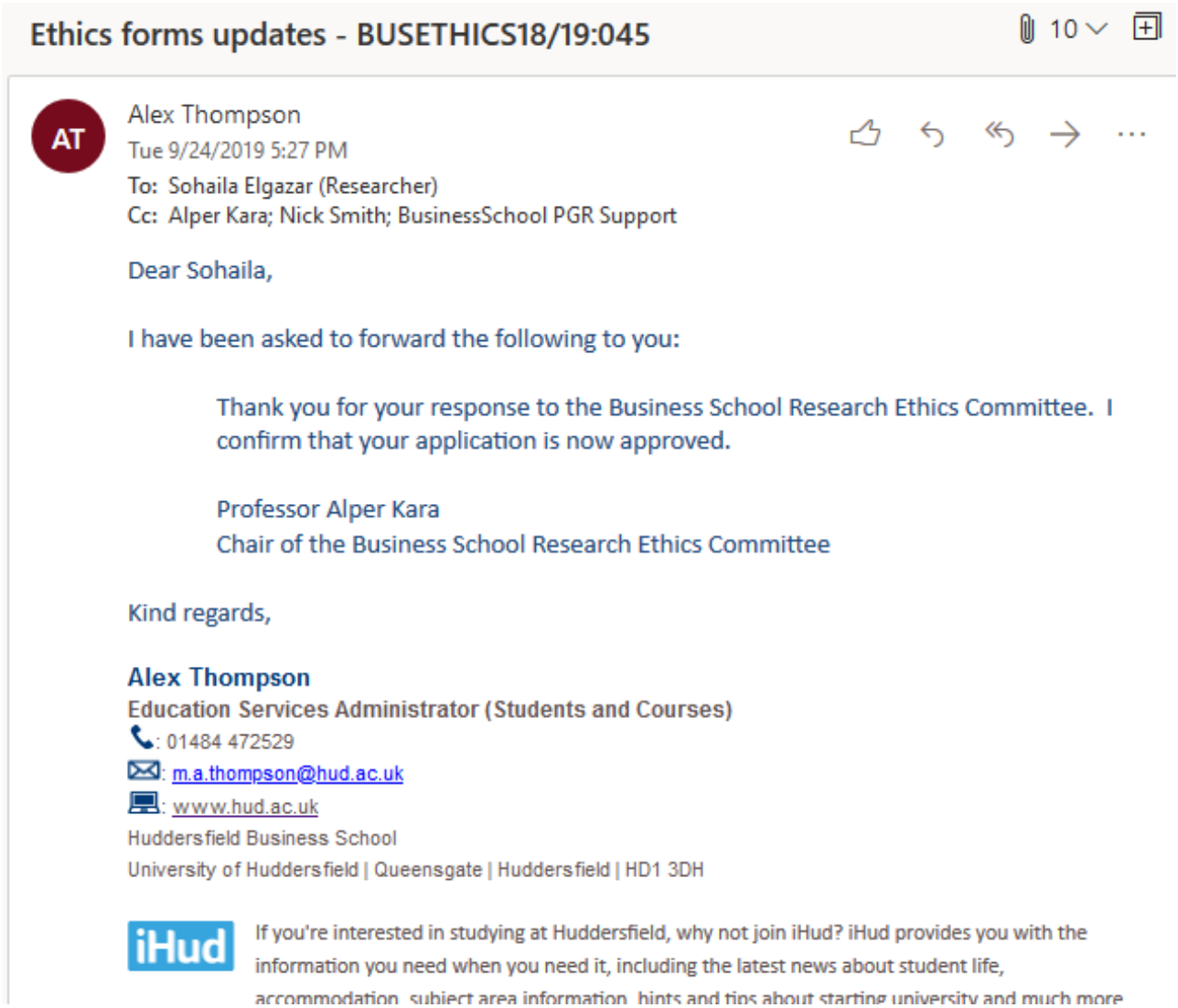
51. d. Driver’s applications for facilitating the trucks' movement and managing the way used * Mark only one oval.

- Agree
- Disagree
- Not sure

An open-ended question:

52. If there is any further information you wish to add, please mention it. *

Appendix Four: Ethics Forms Approval



Ethics forms updates - BUSETHICS18/19:045

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AT

Alex Thompson
Tue 9/24/2019 5:27 PM
To: Sohaila Elgazar (Researcher)
Cc: Alper Kara; Nick Smith; BusinessSchool PGR Support

Dear Sohaila,

I have been asked to forward the following to you:

> Thank you for your response to the Business School Research Ethics Committee. I confirm that your application is now approved.
>
> Professor Alper Kara
> Chair of the Business School Research Ethics Committee

Kind regards,

Alex Thompson
Education Services Administrator (Students and Courses)
: 01484 472529
: m.a.thompson@hud.ac.uk
: www.hud.ac.uk
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