# Capacity Analysis and Optimisation of Traffic Flow at Major Intersections within the East London Central Business District using Quantum Flow Theory: A Case Study of Oxford Street

by

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## DECLARATION

I, the undersigned, declare that the dissertation hereby submitted by me for the degree *Master of Engineering in Civil Engineering* at the Central University of Technology, Free State, is my own independent work and has not previously been submitted by me to another University and/or Faculty in order to obtain a degree. I further cede the copyright of this dissertation in favour of the Central University of Technology, Free State.

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## ABSTRACT

Traffic congestion represents a persistent challenge to the long-term viability of urban transportation systems, affecting numerous cities within and outside South Africa (SA). Projections indicate a worsening trend, posing a significant threat to urban life quality. Congestion detrimentally impacts traffic speed, leading to heightened journey durations, increased fuel consumption, elevated operational expenses, and exacerbated environmental pollution when contrasted with unimpeded traffic flow.

Over recent decades, the escalation of private vehicle ownership across the East London (EL) metropolis has exacerbated traffic congestion, notably within the East London Central Business District (EL-CBD), specifically along Oxford Street. This study endeavours to undertake a capacity analysis and traffic flow optimisation utilising and applying a model grounded in quantum flow theory, aiming to alleviate traffic congestion within the EL-CBD, focusing on Oxford Street.

The study aims to develop an optimised route assignment network design and an Integrated Transportation Plan (ITP) as part of a comprehensive strategy to enhance traffic flow efficiency at the three primary intersections within the EL-CBD. The study collects and analyses data in two phases using a quantitative research methodology. The initial phase entails disseminating and completing a structured questionnaire by 384 respondents. Subsequently, the second phase entails a comprehensive traffic survey conducted for 16 hours daily across seven consecutive days at each intersection to ascertain traffic flow patterns.

The investigation reveals that Oxford Street experiences uncontrolled traffic congestion, particularly during peak hours from 6:00 to 10:00 in the mornings and 14:00 to 18:00 in the afternoons throughout the week. The study attributes this congestion primarily to elevated traffic volumes from increased private vehicle ownership, reckless driving behaviours, and limited parking availability. Identifying and quantifying congestion hotspots has emerged as imperative for decision-makers to devise effective mitigation strategies to enhance the sustainability of the broader transportation network. The paper outlines available measures, comparing and detailing their implementation on historical traffic datasets spanning daily and

weekly. Enhanced public transportation systems, incentivised carpooling initiatives, localised bus services, and judicious parking management are promising strategies for mitigating traffic congestion within the EL-CBD.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| BCMM | Buffalo City Metropolitan Municipality |
| BRT | Bus Rapid Transport |
| CBD | Central Business District |
| EL | East London |
| HOV | High-Occupancy Vehicle |
| ID | Integrated Development |
| IRPTN | Integrated Rapid Public Transportation Network |
| ITP | Integrated Transportation Planning |
| MBT | Mini-Bus Transport |
| NMT | Non-Motorised Transport |
| NRC | Non-Recurrent Congestion |
| NRTLEC | National Road Traffic Law Enforcement Code |
| PNR | Park-and-Ride |
| PT | Public Transport |
| QFT | Quantum Flow Theory |
| RC | Recurrent Congestion |
| SA | South Africa |
| TIM | Traffic Incident Management |

# CHAPTER 1 : INTRODUCTION TO THE STUDY

## 1.1 Background of the Study

The study delves into many issues contributing to the escalating phenomenon of traffic congestion, which persists unabated. Globally, traffic congestion is a prominent challenge afflicting urban agglomerations across developed and developing cities (Singh et al., 2020). This predicament incurs substantial time losses during journeys, while severe congestion impairs labour productivity within densely populated urban centres (Nwankwo et al., 2019). Despite concerted efforts by authorities to mitigate traffic congestion, it remains a persistent issue characterised by a disparity between traffic flow and road capacity. Consequently, travel durations increase, accompanied by elevated costs and aberrant driver and commuter behaviours, exacerbating stress and frustration levels during transit.

Therefore, it becomes imperative to scrutinise the challenges posed by traffic congestion and explore avenues for their mitigation, focusing on harnessing the potential of quantum flow theory to revitalise the East London Central Business District (EL-CBD). East London (EL) emerges as the second economic nucleus of the Eastern Cape region, attracting a substantial influx of commuters from surrounding satellite towns such as Mdantsane, Maclean Town, Berlin, and Ducat South, owing to the urban sprawl catalysed by its economic significance. Nonetheless, a conspicuous knowledge gap persists, necessitating this study to bridge the existing lacuna.

### 1.1.1 Study area

The study was conducted within the EL-CBD in the Buffalo City Metropolitan Municipality (BCMM), Eastern Cape Province, South Africa. With its CBD serving as the hub for public services, business activities, and urban mobility, EL is a significant economic and transportation hub. Due to its high concentration of retail stores, office buildings, public transportation terminals, and educational institutions, the area experiences much pedestrian and vehicular traffic, especially during peak hours.

The study's focus is Oxford Street, one of the main arterial roads that crosses the EL-CBD. High traffic volumes, frequent signalised intersections, and various vehicle types, including delivery trucks, buses, minibus taxis, and private cars, are characteristics of Oxford Street.

While empirical studies specifically targeting traffic congestion within the EL-CBD are scarce, addressing this issue comprehensively within the city's context is imperative. Consequently, the current study endeavours to contribute novel insights into traffic congestion mitigation strategies tailored to bolster economic activity by augmenting the mobility of East London's transportation infrastructure.

**Figure 1.1: Aerial view of East London CBD, Eastern Cape, South Africa.**

*Source: Google Maps, satellite imagery. Accessed May 12, 2023.*

## 1.2 Problem Statement

Traffic congestion represents a persistent challenge, posing multifaceted hurdles for transportation stakeholders and policy decision-makers. Like numerous other urban locales, the burgeoning population growth in East London (EL) exacerbates strain on the city's already congested thoroughfares. Intersections along Oxford Street suffer from recurrent and protracted delays in traffic flow, underscoring the imperative for proactive measures to accommodate burgeoning population growth while upholding service quality and operational efficiency.

A confluence of factors contributes to the genesis of traffic congestion, including the escalating ownership of private vehicles and the influx of migrants from rural hinterlands to urban centres (Tiwari et al., 2023). This phenomenon is intricately linked to the efficacy of transportation systems within South African urban landscapes in mitigating transportation bottlenecks (Feikie et al., 2018). The traffic congestion observed on Oxford Street is not isolated but replicates a broader national trend of growing urban traffic congestion in South Africa. This trend is driven by rapid urbanisation, limited public transport infrastructure, and a growing reliance on private vehicles. Similar patterns are evident in major cities such as Johannesburg, Cape Town, and Durban, where urban corridors experience frequent bottlenecks during peak hours (McKay, 2020). Thus, addressing congestion on Oxford Street provides insights into systemic inefficiencies and potential interventions applicable at a national scale.

South Africa's reliance on private vehicles is high due to the lack of reliable, affordable, and efficient public transport systems (Shange & Harmáček, 2017). At the same time, large cities like Johannesburg and Cape Town have better-established public transport networks, while smaller cities like East London lack integrated solutions (Kelsall et al., 2021).

The resultant challenges reverberate across various domains, adversely impacting the timely delivery of essential services and goods, thereby exerting detrimental effects on the economy.

## 1.3 Research Aim(s) and Objectives

### 1.3.1 Aim

This study endeavours to undertake a comprehensive capacity analysis and optimisation of traffic flow within the East London Central Business District (EL-CBD), specifically along Oxford Street, employing quantum flow theory at three pivotal intersections. Adopting this innovative approach can ameliorate traffic congestion and enhance the overall safety and efficiency of mobility in the targeted area. Apart from contributing to the current corpus of knowledge concerning road traffic management techniques and tactics, this study aims to demonstrate approaches for controlling traffic congestion in the EL-CBD area using quantum flow theory.

### 1.3.2 Objectives

- The main objective of this endeavour is to employ quantum flow theory to identify congestion triggers and delay factors across the major intersections of Oxford Street. Subsequently, a meticulous analysis of the collected data will be conducted to discern patterns and insights, culminating in the formulation of an optimised route assignment network design in Chapter Four. This design aims to bolster safe mobility and operational efficiency within the targeted area, leveraging the principles of quantum flow theory.

- Another focal point of this initiative involves the development of a comprehensive Integrated Transportation Plan (ITP), leveraging the insights gleaned from the quantum flow traffic method and the data acquired along Oxford Street. The envisioned ITP will serve as a blueprint for enhancing the innovative city design paradigm, integrating alternative charter preferences and forward-looking transportation strategies to foster sustainable urban development and resilient urban ecosystems.

## 1.4 Significance of the Study

The imperative to address traffic congestion and navigate the intricacies of transportation policy and regulation falls squarely upon national, provincial, and regional road authorities, alongside policymakers, transport engineers, and urban planners. Their collective mandate encompasses formulating and implementing strategic interventions to manage challenges and optimise traffic flow within the land use and transportation sectors. Simultaneously, vehicular transport users, comprising drivers and commuters, require robust transportation systems characterised by operational efficiency and enhanced safety to facilitate seamless mobility.

Central to this endeavour is a comprehensive traffic study, a meticulous process involving exhaustive examination and thorough analysis of the transportation ecosystem in a designated locality. Drawing upon a wealth of data, this study is the cornerstone for evaluating persistent transportation challenges and devising viable solutions to alleviate traffic congestion in East London (EL) and potentially other urban centres grappling with similar predicaments (Xia et al., 2021).

The outcomes of this study are poised to exert a significant influence on the operational dynamics of cities and road networks at large. Equipped with insights from this research endeavour, traffic engineers are empowered to devise tailored solutions encompassing roadway design enhancements and sophisticated traffic control mechanisms. At its core, this study is driven by the overarching objective of furnishing drivers with a secure and efficient framework for vehicular movement.

Moreover, the insights gleaned from this study hold immense value for national, provincial, and regional road authorities, lawmakers, urban planners, and transportation strategists alike. By offering a comprehensive assessment of potential solutions to the mobility conundrum, this research endeavour is poised to inform strategic decision-making processes to bolster transportation infrastructure and foster sustainable urban mobility paradigms.

## 1.5 Limitations of the Study

This section delineates the constraints encountered during the research project. Throughout the study, a spectrum of limitations came to the fore. Age neutrality was upheld, ensuring equitable participation among all demographics. Nonetheless, the researcher grappled with various constraints during the research process, prompting the formulation of recommendations pertinent to future investigations. Identified limitations encompass the following:

- Geographic scope: The study's geographical focus was confined to East London's Oxford Street, thereby precluding the generalisability of results to broader contexts.
- Participant composition: The study targeted drivers and commuters traversing Oxford Street throughout the week, thus potentially excluding one-time users of the thoroughfare.
- Sampling bias: In the quantitative data collection phase, the administration of questionnaires favoured individuals present within the East London Central Business District (EL-CBD) during survey implementation, potentially introducing sampling bias.
- Sample size constraints: A limitation stemming from sample size availability was observed. Despite using a simple random sampling method to distribute questionnaires to 384 respondents, this Figure falls short of accurately representing the population of East London, which exceeds the sample size by a considerable margin.
- Sampling error: The study did not include a formal evaluation of sampling error, such as computing margins of error or confidence intervals. Because of this, even though the sample size seems representative, it is impossible to fully quantify the accuracy and statistical reliability of the survey results. This restricts how broadly the findings can be applied with a certain degree of statistical confidence.
- Vehicular traffic volume: There are inherent limitations related to the volume of vehicular traffic along Oxford Street, even though the survey had a respectable response rate, gathering data from roughly 16% of all through traffic. A greater percentage of drivers could not be surveyed due to the high

traffic volumes without causing significant disruptions or necessitating additional logistical support.

- Resource constraints: The survey's scope was limited by the financial and human resources at hand, which also affected the length of time and coverage of data collection. These restrictions might limit how broadly the results can be applied to all road users, especially in off-peak hours or in different traffic situations.

## 1.6 Dissertation Outline

In this section, an overview and summary of the five chapters comprising the study are provided, delineating their respective roles in addressing the subject of traffic congestion:

**Chapter 1**: ***Background and Problem Statement***. This chapter sets the stage by presenting the background of the study on traffic congestion, accompanied by a comprehensive problem statement. It delves into pertinent traffic flow issues specific to East London (EL) while contextualising the global traffic congestion trend within the South African (SA) landscape. Emphasis is placed on elucidating the study's aims, objectives, significance, and delineating inherent limitations.

**Chapter 2**: ***Literature Review***. Chapter 2 thoroughly reviews existing literature, providing insights into urban transportation dynamics within the South African context. Topics covered include an examination of tools for modelling travel patterns, the pivotal role of policymakers in mitigating traffic congestion, and an exploration of various strategies for its management. Additionally, the chapter scrutinises shifts and trends observed in South African urban transportation, alongside discussions on the metropolitan transportation system, urbanisation, and systemic challenges therein.

**Chapter 3**: ***Research Methodology***. This chapter elucidates the research methodology adopted in the study, alongside discussions on its inherent limitations and ethical considerations. Employing a quantitative approach, the study integrates both primary and secondary data sources in the data collection process. The distribution of a quantitative questionnaire, facilitated by a simple random sampling methodology, serves as the principal data acquisition mechanism.

**Chapter 4**: ***Results and Data Analysis***. Chapter 4 presents the study's outcomes, encompassing quantitative data analysis, including descriptive data analysis of information gleaned through the questionnaire. Through systematic examination, the chapter elucidates key findings from the collected data.

**Chapter 5**: ***Discussion, Conclusions, and Recommendations***. The final chapter synthesises the research findings, providing a comprehensive discussion and summarising the study's results vis-à-vis its research objectives. Additionally, it offers conclusions pertinent to the overarching research goals. The chapter culminates with recommendations for future research endeavours, delineates the study's contributions and limitations, and proposes ideas for a potential research proposal.

# CHAPTER 2 : LITERATURE REVIEW

## 2.1 Concept of Traffic Flow

This chapter delves into the complexities of the transportation system, particularly focusing on the urban transportation challenges within South Africa, with a particular emphasis on the traffic congestion phenomenon. Seid et al. (2020) posited that the root cause of traffic congestion lies in the imbalance between demand and supply within the transportation network. Increased vehicular presence on roadways leads to congestion, resulting in diminished traffic flow and reduced road capacity due to various factors. The consequences of congestion are manifold, encompassing prolonged travel durations for drivers and passengers, heightened fuel consumption, escalated greenhouse gas emissions, and an elevated risk of vehicular accidents. Hence, a comprehensive review of traffic congestion studies assumes significance in fostering the development of practical Intelligent Transportation Systems (ITS) to promote safe and efficient mobility.

This study's focal data collection and analysis area is the Central Business District (CBD) of East London (EL), situated along Oxford Street within South Africa's Eastern Cape Province. The coordinates of Oxford Street commence at the R72 route, positioned at latitudes 33.0196 and longitudes 27.9052, and culminate at Lukin Road, situated at latitudes 32.9963 and longitudes 27.8974. EL is the province's second-largest industrial hub, with the automotive industry as its principal employer. As of 2023, the estimated population of EL stands at 463,651, positioning it as one of South Africa's 50 major cities, ranking 15th in terms of population size. The city is interlinked with other significant urban centres in the country, including Gqeberha, Port Alfred, Queenstown, and Mthatha, via national routes N6, N2, and R72. The CBD comprises commercial districts, governmental offices, professional service establishments, banking institutions, taxi ranks, medical facilities, law enforcement precincts, postal services, libraries, tourist attractions, recreational venues, and places of worship. Additionally, commercial activities within the CBD encompass expansive retail complexes such as shopping malls, marketplaces, and informal street-side vendors.

## 2.2 Overview of Urban Transport in SA

An urban transportation system encompasses all city transportation elements, including infrastructure, rolling stock, and traffic flows, functioning as an integrated entity (Kruszyna, 2021). Given the dense concentration of human activities within confined urban spaces, traffic congestion is a pervasive issue, particularly evident in commercial and business districts across large cities nationwide. Effective planning of urban freight movement is imperative not only to sustain the economic vibrancy of urban centres but also to contribute to the advancement of sustainable urban transportation.

Cities retain their status as hubs of economic activity, underscoring the importance of well-coordinated and accessible transportation networks for people and goods (Levinson, 2012). Urbanised areas necessitate transportation systems capable of seamlessly connecting diverse activities such as residential zones, commercial establishments, and industrial precincts, thereby ensuring the functionality and attractiveness of cities to inhabitants (Chao et al., 2019). The ensuing section delineates the classifications of urban transportation systems, and the attendant challenges encountered in South Africa.

### 2.2.1 Classification of urban transport systems available in SA

The South African government allocates significant financial resources toward local transport infrastructure to facilitate smooth commuting for road users (Tirachini & Cats, 2020). Despite substantial investments, the country continues to grapple with inadequate infrastructure. Notwithstanding the array of transportation options available, South Africa faces numerous challenges in its transport sector, encompassing low ridership, limited access to public transportation in rural locales, equity disparities, and congestion. The efficacy of a transportation system profoundly impacts the efficiency of commuter, goods, or logistics movement, spanning inbound, throughput, and outbound processes. However, in the case of EL-CBD, traffic congestion impedes the reliability and efficiency of transportation operations (Mulangi & Kulkarni, 2022). The subsequent sections delve into the classification of urban transportation systems prevalent in South Africa and the attendant challenges of this classification and operational modalities.

**Urban bus systems in South Africa (SA):** In South Africa, bus services face multifaceted challenges, encompassing concerns related to reliability and safety. Advancements in bus systems are imperative to curtail the escalating reliance on private vehicles and mitigate their adverse environmental impacts (Sam et al., 2018). The Bus Transit system is perceived as a safer alternative than other public transport modes, particularly regarding traffic flow optimisation. However, in EL, infrastructure and management system deficiencies result in inadequate bus service coverage along specific routes. Commuters have limited options, often necessitating long walks or alternative supplementary transportation modes to reach their destinations. Consequently, many EL commuters opt for private cars, undermining efforts toward traffic flow optimisation.

Substantial enhancements in service quality within municipal or communal transportation are imperative for regulations and policies to facilitate modal shifts from private vehicles to public transportation to yield desired outcomes (Heyns & Luke, 2017). The subsequent section delves into the municipal or commuter bus services landscape in South Africa, addressing pertinent issues and potential avenues for improvement.

**Municipal or commuter bus services:** The state of communal transportation infrastructure holds significant importance for South Africans and is considered nearly as vital as education and health (Heyns & Luke, 2017). Majam and Uwizeyimana (2018) underscore that economic development is a key priority for local governments, as outlined in municipalities' Integrated Development (ID) plans to enhance living standards across communities nationwide. When municipal or commuter bus services are operationalised, they typically utilise fuel-efficient vehicles, resulting in a reduced carbon footprint compared to individual car usage (Isik et al., 2021). Commuters using public transportation often benefit from increased social interaction and a sense of community.

Moreover, commuter bus services alleviate strain on roads and highways, leading to smoother traffic flow (Hossain & Taz, 2023). By extending services to underserved or rural areas, public transportation fosters accessibility and mobility for all community residents. Particularly in urban locales with high parking and fuel costs, municipal or commuter bus services may present a more economical alternative to owning and maintaining personal vehicles.

However, Risimati (2021) highlights widespread grievances among bus passengers, notably regarding service availability. Challenges such as buses not reaching desired destinations, distant bus stops from residential areas, and inadequate awareness of routes and schedules often lead commuters to opt for taxis or private vehicles. Additionally, according to Netshisaulu (2022), reliance on buses operating on schedule can strain commuters' punctuality, affecting their professional relationships and perceptions of reliability.

In the context of the current study aiming to optimise traffic flow in EL-CBD, the inefficiency of commuter bus services stands out as a key driver behind the preference for private car usage. Poor management systems and inadequate road infrastructure contribute to the shortcomings of commuter bus services in EL, compelling commuters to seek alternative modes of transportation to reach their destinations efficiently.

**Bus Rapid Transport (BRT) System:** Bus Rapid Transit (BRT) systems play a pivotal role in South African urban mobility, contributing to economic growth, job creation, and tourism. Scorcia and Munoz-Raskin (2019) note that South African cities embraced BRT systems following the success observed in Latin American cities. Beier (2020) adds that BRT projects are often undertaken to position cities as sustainable or world-class, enhancing the standing of urban residents, workers, and bus passengers. Numerous studies, including those by Merkert et al. (2017) and Venter et al. (2018), emphasise the functional superiority of BRTs over other transit modes. BRT systems typically offer enhanced convenience, speed, connectivity, and reliability across various service aspects. Compared to conventional public transit systems and mixed-flow traffic lanes used by automobiles, BRT systems provide improved travel times, consistency, safety, and speed (Das & Ahmed, 2021).

**Mini-bus taxi (MBT) system:** The mini-bus taxi (MBT) industry is a crucial component of public transportation systems in South African cities, as highlighted by Schalekamp and Klopp (2018). In EL, mini-bus taxis are a ubiquitous and popular mode of urban transport, known for their adaptability and convenient routes that offer commuters access to various transit options. According to Mehran et al. (2020), taxis demonstrate agility in network operations, allowing them to provide flexible door-to-door services by adapting to any available route. Despite their popularity, mini-bus taxis are typically more expensive than buses and trains due to the lack of government subsidies (Hensher, 2017). Despite allegations of conflict, violence, and criminal activity, the mini-bus taxi sector continues to grow and significantly contribute to the nation's economic development (Geldenhuys, 2019; Martin, 2021).

However, the industry has garnered a negative reputation due to persistent conflicts and instances of aggression. While mini-buses serve many passengers, the quality of service in EL is often unsatisfactory due to driver behaviour and reckless driving issues. Additionally, some vehicles operate with illegal documentation, as noted by Kerr (2018). Many mini-bus taxis operate without proper licenses, and drivers often lack legal permits. These challenges underscore the complexities of urban transportation systems and the need for comprehensive solutions.

### 2.2.2 Challenges within an urban transportation system

The city of EL is experiencing a pressing demand for improved transportation services, necessitating the development of a more efficient transportation system. However, as noted by Duy et al. (2019), the transportation infrastructure in major cities is becoming increasingly susceptible to various challenges. Urban development often leads to cities' spatial expansion, and their transportation systems' effectiveness becomes crucial for sustaining urban productivity (Rodrigue, 2020). Several challenges within urban transportation systems have been identified and explained in the subsection below.

**Insufficient public transport (PT):** The lack of integration among different modes of public transportation poses a significant challenge to establishing a cohesive, sustainable, and efficient public transportation system (Cele, 2018). Overcrowding in public transportation has decreased commuters' expectations of privacy (Das et al., 2021). This issue is exacerbated by the frequent inadequacy of service levels, preventing public transportation from effectively competing with private vehicles in terms of meeting commuters' expectations (Suman & Bolia, 2019).

**Car parking facilities:** In metropolitan areas where space is limited, the demand for parking has surged alongside the expansion of vehicle ownership (Hoehne et al., 2019; Mingardo et al., 2015). This heightened demand has led to vehicles parked in prohibited areas within the EL-CBD, exacerbating traffic congestion. A parking policy is considered the primary solution to address parking issues within and outside city limits (Ostermeijer et al., 2022). However, parking regulations require regular review, and technological advancements are being explored to address space shortages and the traffic congestion resulting from vehicles circling in search of parking spots (Lam & Yang, 2019).

In the EL-CBD, high vehicle ownership rates have made parking a contentious and complex issue. Parking challenges can arise in various locations such as airports, bus terminals, and shopping malls, impacting nearby businesses and residents' quality of life (Forouhar et al., 2022). Consequently, cities continually reassess and refine parking strategies and performance metrics, recognising the critical role of parking in urban mobility. Common challenges faced in the EL-CBD include insufficient information for drivers regarding parking availability and costs, suboptimal utilisation of existing parking capacity, high levels of vehicle ownership, inadequate loading and unloading zones, and limited parking at event venues.

### 2.2.3 Difficulties for non-motorised transport (NMT)

Non-motorised transportation (NMT) offers many benefits, including being cost-effective, efficient, and conducive to good health, particularly for short-distance travel, in contrast to vehicle usage (Mbatha et al., 2021). However, the efficacy of public transportation services catering to all user needs can be compromised if NMT infrastructure is not adequately prioritised by governmental and societal entities (Mabe & Chauke, 2019; Cele, 2018). Consequently, NMT users often use facilities not designed for their mode of transport, leading to unfavourable conditions and a mismatch between infrastructure and user expectations.

## 2.3 Travel Demand Modelling Tool

Travel demand models forecast future travel patterns based on a sample of past travel behaviour data by utilising current travel behaviour (Rashidi et al., 2017). Models are essential tools for planners and engineers to predict the transportation needs of the communities they serve. Informed transportation planning decisions can help planners prepare for future traffic growth by utilising the output of a travel demand model (Waddell, 2016). The section below starts by presenting urban sprawl, followed by travel demand explained below.

### 2.3.1 Urban sprawl

According to Seevarethnam et al. (2021), urban sprawl is the growth of urban developments (like homes and shopping malls) on undeveloped land close to a city. Urban sprawl is defined as the unchecked expansion of roads, housing, and commercial space across sizable tracts of land in many urban areas, with little regard for urban planning (Shao et al., 2021). Urban sprawl affects many cities in SA, including EL, due to the rapid development of housing communities surrounding the town, which results in urban population growth (Marais et al., 2020). It increases reliance on private car ownership for transportation from the surrounding residents to the city for services. Also, it has to do with the effects of this development on society and the environment (Zhao, 2010).

Increased travel times, transportation expenses, pollution, and rural area degradation are some contemporary drawbacks and expenses. Urban infrastructure construction costs for new developments are rarely covered by property taxes, meaning that current property taxpayers foot the bill for the developers' and newcomers' subsidies (Merk et al., 2012).

### 2.3.2 Travel demand models

In the past, transportation planners have placed a greater emphasis on building new infrastructure to meet the current and rising demand for travel. Scholars have redirected their attention over the last few decades from creating new infrastructure to ensuring sustainable transportation systems satisfy evolving demands (Verma & Ramanayya, 2014). This can be accomplished by employing efficient travel demand models to manage travel demand effectively.

According to Rafiq and McNally (2023), the trip-based approach analyses trips as the unit of analysis and views a person's daily travel pattern as accumulating several independent trips. Owing to its autonomous nature, the conventional four-phase travel demand approach blatantly disregards the relationships among the numerous aspects of distinct journeys, including duration, location, and mode of transportation (Kirabo, 2023).

Furthermore, the trip-based method ignores the scheduling of trips and the ensuing inter-relationship in the attributes of multiple trips at every stage (Dannemiller et al., 2023). According to Oughton et al. (2021), many activities performed outside the home are replaced with corresponding activities done inside due to internet and telecommunications infrastructure advancements. The traditional approach treats each trip as an independent entity and only considers trips, disregarding temporal and spatial interrelationships (Jones, 2021).

## 2.4 Role of Policymakers in Traffic Congestion

Traffic accidents frequently result from traffic congestion as drivers attempt to move through congested roadways more quickly than other motorists (Agyapong & Ojo, 2018). Emergency vehicles such as ambulances and fire-fighting vehicles would have priority under any system or policy established for a priority-wide range to get special classes of vehicles to prioritise the safety of society while facing the traffic congestion phenomenon. Related policies can be suggested based on the assessment of PT operations to achieve the required congestion reduction (Hensher, 2018).

With significant financial commitments and carefully thought-out legislative tools to advance and promote public transportation, the SA government implemented approaches and guidelines to endorse PT systems (Ramirez-Rubio et al., 2019). According to Thondoo et al. (2020), policies that discourage using private vehicles must be implemented to create room for a sustainable and healthful transportation system. The traffic congestion management in SA is presented in the following sections.

## 2.5 Managing Traffic Congestion in SA

Numerous cities have adopted a range of traffic congestion mitigation techniques in place of expanding infrastructure capacity to control traffic congestion (Nugmanova et al., 2019). Several measures have been implemented in South Africa to decrease traffic volume and the concentration of private automobiles on the roads, such as the BRT and rapid rail networks. This section begins with an overview of various definitions, types, and causes of traffic congestion and solutions.

### 2.5.1 Concept of road traffic congestion

Although "traffic congestion" has been defined in various ways, there is still no universally accepted definition (Handy, 2020). Koźlak and Wach (2018) define traffic congestion as when there is more vehicle traffic than a given road can handle, which causes traffic flow to decrease. The number of cars attempting to use a roadway at any given time exceeds the road's capacity to handle the load at generally adequate service levels, according to Singh et al. (2020). This is known as traffic congestion.

Moreover, an excessive number of motor vehicles on the road network leads to unusual declines in service quality marked by variations in travel times, which is referred to as traffic congestion (Olayode et al., 2020; Lessan & Fu, 2019). When there are delays in travel times and lengthy lines, the road network's capacity is exceeded due to increased use of transportation networks. This is called traffic congestion (Das & Keetse, 2016).

According to the definitions, this study found that congestion comprises networks, the excessive use of road space, slower speeds, longer travel times, and car lines. Thus, roads with low traffic flow and high traffic volume, comprising buses, trucks, heavy vehicles, and passenger cars, can exhibit congestion.

### 2.5.2 Categories of road traffic congestion

Given the sharp increase in demand for urban travel, the nation's urban transportation system has significant supply-side constraints. The struggle between rapidly increasing traffic demand and inadequate road volume within urban motorway systems has evolved gradually in modern times due to the growth of the social economy (Ma et al., 2020). Thus, as will be covered in more detail below, traffic in urban systems can be classified into recurring and nonrecurring congestion.

**Recurrent congestion (RC):** A continuous flow of vehicles usually creates this kind of traffic jam, which generally happens on a permanent road during the morning and afternoon rush hours. Common causes include inadequate traffic infrastructure, inadequate traffic capacity, and poor signal control (Keler et al., 2017). Recurrent congestion (RC) is brought on by routine traffic in an anticipated scenario. In contrast, nonrecurring congestion is unanticipated and most likely the result of an incident, according to Ahsani et al. (2019).

Bako and Agunloye (2017) suggest that the increasing use of private vehicles, urbanisation, and population growth may be associated with these incidents. Inadequate transportation systems, synchronised work and school schedules, urban population growth, and many businesses moving from mid-city areas to the suburbs all contribute to congestion (Diaz, 2017). The road networks in EL-CBD experience RC during peak hours due to high vehicle ownership and excessive or insufficient use of other roads.

**Non-recurrent congestion (NRC):** Agyapong and Ojo (2018) claim that accidental and unplanned events cause non-recurrent congestion (NRC). The irregular nature of the occurrences can be attributed to multiple factors, including the emergence of construction sites, road closures, and accidents (Keler et al., 2017).

While many factors contribute to traffic congestion, including inadequate infrastructure, emergencies, unconstrained demands, and ineffective capacity management (e.g., poor timing of traffic), NRC is primarily caused by sporadic events, including climate change, road construction, vehicle breakdowns, employment zones, special occasions, and events of note (Afrin & Yodo, 2020). As a result, random events lead to NRC on the road network.

### 2.5.3 Peak hours of traffic congestion

During the morning and afternoon peak hours, the level of road congestion is unquestionably higher than the average values (Zhao & Hu, 2019). Peak hours are the morning and evening hours when traffic congestion is the most frequent, and the average speed constantly drops below 60 km/h (Mkulisi & Sinclair, 2021).

Congestion during rush hours has become the primary concern in most cities worldwide as more people travel frequently for work-related reasons, particularly during rush hours (Chatterjee et al., 2020). Even though many cities have focused on making motor vehicle movement more efficient, the construction of metropolitan roadways has resulted in high levels of private car usage and congestion (Hickman et al., 2018).

According to Onderwater (2019), the real peak hours in Cape Town are roughly from 6:00 to 9:00 in the morning and from 4:00 to 7:00 p.m. This is one hour later than in Durban. The city started programs to encourage telecommuting, which will free up the roads from many commuters during peak travel hours, to impress the populace by reducing traffic congestion (Hensher et al., 2021).

### 2.5.4 Factors contributing to traffic flow congestion

The urban transportation system is becoming increasingly vulnerable to various traffic congestion-related issues (Duy et al., 2019). Although these issues are manageable, surprisingly few solutions have been provided thus far. Because urban productivity depends on the efficient functioning of its transportation system, cities are spatially expanding alongside urban development (Rodrigue, 2020), and the following problems have been identified with urban transportation systems.

**Rise in vehicle ownership trend:** Over the past few decades, there has been a discernible increase in vehicle ownership worldwide (Saeidizand et al., 2022). Increased income, urbanisation, and easier access to financing have all contributed to this trend, which has made cars more affordable for a larger group of people (Zhang, 2016).

In developing nations, the use of automobiles and car ownership have surged dramatically due to modernisation, rapid economic growth, and the building of new road infrastructure (Verma et al., 2021). Traffic congestion is a major problem in metropolitan areas due to the significant increase in car ownership and travel demand worldwide. Rose et al. (2017) state that insufficient public transportation is the leading cause of excessive car ownership in SA.

Urban areas may see severe traffic congestion as more people own cars, which lowers the standard of living for locals and adds to the time and fuel spent commuting (Othman & Ali, 2020). According to Marshall and Dumbaugh (2020), traffic congestion can affect productivity by causing inefficiencies in transportation systems and increased expenses for individuals and businesses.

Rising car ownership has strained existing infrastructure, including parking lots, roads, and public transportation systems (Mattioli et al., 2020). The increasing number of vehicles may make it difficult for local governments to expand infrastructure, which could result in traffic jams or a decline in the quality of the roads (Singh and Singh, 2021).

Although owning a car has many advantages, including convenience, economic expansion, and personal freedom, some drawbacks must be considered (Oladimeji et al., 2023). The ramifications include social repercussions, infrastructure stress, health hazards, and environmental issues. Many cities are looking into sustainable transportation options to reduce adverse effects, like promoting electric vehicles, increasing public transportation, and incorporating walking and bicycling into urban planning (Alanazi, 2023).

**Population growth:** EL's population growth has not been matched by the proportionate construction of new roads, resulting in traffic congestion (Ewing et al., 2018). This places significant pressure on local, provincial, and national governments to build transportation infrastructure to meet the growing demand for population mobility and goods transportation. In SA, urban areas accommodate a large proportion of the population (Mlambo, 2018).

In addition to causing environmental harm like air pollution and traffic congestion, university students and worker migration strain social welfare systems (Hsiang et al., 2020). Several factors, including population growth, urbanisation, suburban sprawl, rising incomes, and an increase in the ownership and use of motor vehicles, cause the urban transport crisis in the city of EL. According to Elmansouri et al. (2020), a growing population encourages infrastructure construction to meet constantly evolving demands, promoting urbanisation.

**Inadequate public transport:** The purpose of public transportation is to transport people to various locations. According to Cele (2018), the biggest obstacle to providing a cohesive, long-lasting, and effective public transportation system is the lack of integration between the different public transportation options. Customers are not happy with PT, and they no longer have as high expectations for privacy. Because PT's service levels frequently fall short of commuters' expectations, it cannot compete with private vehicles in this regard (Suman & Bolia, 2019). Because public transportation is not that good, people are more likely to use private cars, which puts more traffic on the roads.

**Limited parking space facilities:** The parking crisis has evolved in urban planning as vehicle ownership has increased, despite insufficient space within cities (Hoehne et al., 2019). Cars Park in green spaces, lawns, walkways, recreation areas, and residential driveways because there are insufficient parking facilities in cities. This leads to traffic congestion and may cause delays for emergency services vehicles (Duvanova et al., 2016).

Putting in place a parking policy is the primary tool for regulating parking problems both within and outside of EL. According to Lam and Yang (2019), parking regulations must be reviewed. Additionally, technology is currently being developed to mitigate space shortages and the congestion brought on by cars circling looking for parking spots (Weinberger et al., 2020).

**Road construction and maintenance projects:** Road construction zones are bad for traffic safety because they lead to traffic jams and accidents, which in turn cause delays. Yousif et al. (2017) state that heavy traffic demand exceeding the roadway's capacity, or perhaps due to incidents or accidents, is the primary reason for traffic jams at construction sites.

### 2.5.5 Strategies for managing traffic congestion

Roadblocks cause delays, frustration, and financial losses for drivers and pollute the air. To adopt mitigation techniques and ensure the sustainability of the entire transportation system, it is critical to pinpoint the areas that are crowded (Afrin & Yodo, 2020).

Due to the high level of traffic in urban areas, the road networks become congested and can no longer handle the volume of traffic. Strategies for reducing traffic congestion differ between cities, according to Segola and Oladele (2016). The following sections examine various methods for reducing traffic congestion in city centres.

**Enhancing public transport:** Public transportation is necessary for traffic to move efficiently on the roads, but in cities, it often faces difficulties (Leonard et al., 2020;

Luke & Heyns, 2020). Nevertheless, several nations have worked to increase access to public transportation services by restricting the use of private vehicles (Mulley & Kronsell, 2018). For instance, South Africa's government established a public transportation division to accelerate the sector's improvement by introducing an Integrated Rapid Public Transportation Network (IRPTN).

**Enhancement of transport infrastructure:** Good infrastructure, such as well-maintained roads, can be used to gauge a nation's economic development (Eke & Ogba, 2021). Road mobility offers financial benefits, and transportation improvements are frequently advised to promote growth, according to Gibbons et al. (2019). Economic growth can be seen in reducing congestion by infrastructure upgrades (Harahap et al., 2018; Litman, 2021). Expanding road networks and capacity is the simplest way to relieve congestion.

The reality is that due to the poor road infrastructure in the nation, South Africans cannot adequately enjoy the social and economic possibilities of transportation (Sewell et al., 2019). Deprived, inaccessible, and segregated infrastructure development is solely responsible for continuing poverty. Various populations are poor because public transportation, such as work prospects, does not adequately connect them to their destinations.

**Carpooling:** The advancement of several technologies is accelerating the development of mobility (Mounce & Nelson, 2019). Although carpooling has long been popular, smartphone and internet technologies have led to a resurgence of the practice in recent years. According to Ferrero et al. (2018), the rise of carpooling as an innovative, environmentally friendly transportation is replacing ownership as the primary means of personal mobility for service usage. As stated by Mugion et al. (2018) and Acheampong and Siiba (2020), the service is viewed as a low-cost, socially and environmentally sustainable mode of transportation.

Olszewski et al.'s (2018) research supports the notion that users prefer carpooling over public transportation for several reasons, including cost and time saving, consistency, and social benefits. Due to the good perception of ridesharing as a form of transportation, to improve the ridesharing expertise, travellers also like the concept of service integration with social networks (Lasmar et al., 2019; Mounce & Nelson, 2019). Xia et al. (2019) claim that despite carpooling being a sensible way to ease traffic congestion, the primary reasons for its popularity are social mistrust and expensive travel.

According to Metz (2018), even if using public transportation could reduce traffic issues, it can still be prohibitively expensive for some people. Therefore, a significant amount of traffic would be reduced if commuters, particularly daily commuters, adopted carpooling as an effective way to minimise traffic congestion and air pollution (Bruck et al., 2017; Guidotti et al., 2017).

**Promotion of non-motorised transport (NMT):** Appropriate operating arrangements for NMT and public transportation systems would contribute to the community's usefulness and well-being (Calvo & Ferrer, 2018; Thombre & Agarwal, 2021). According to Cooke et al. (2019), the possible environmental, social, and health benefits for pedestrians and cyclists have sparked interest in NMT recently. Walking and cycling can be used strategically to benefit society by contributing to community health improvement, serving as a form of recreation, and promoting social welfare by increasing chances for interpersonal cooperation (Majee et al., 2020).

It is believed that NMT has non-durable well-being, compared to other forms of transportation. It has a significantly reduced environmental impact, whilst being a good form of transportation essential for short-distance trips.  In addition, Mokitimi and Vanderschuren (2017) stated that the utilisation of community facilities has decreased due to poor connectivity, inaccessible road infrastructure, and pedestrian deaths. However, while well-connected road networks would promote NMT, commuters who lack driving and cycling skills would be discouraged from utilising the mode due to a lack of laws and regulations (Risimati & Gumbo, 2019).

**Park-and-ride (PNR) facilities:** Private vehicle owners use public transportation to enter the CBD and leave their cars in the designated parking lot outside the city (Thombre & Agarwal, 2021; Mounce & Nelson, 2019).

The park-and-ride (PNR) system's primary goal may be to discourage the utilisation of private automobiles. Still, encouraging commuters to take public transportation for some of their routes also helps reduce traffic congestion (Ibrahim et al., 2020). However, because they require drivers to access their automobiles, the facilities do not offer much to help the population's most vulnerable groups. According to Kimpton et al. (2020), personal vehicles are only used for a specific portion of the route to facilities in low-density periphery or urban areas. Users can avoid traffic jams and exorbitant parking fees by switching to public transportation.

PNR facilities are frequently found near express bus services in SA (Webb & Khani, 2020), so a desirable facility should be situated there (Rith et al., 2019). In SA, PNR facilities are typically accompanied by rail systems.

## 2.6 Theory and Model Supporting Urban Transport Planning

This section explores the theoretical foundations of urban transportation planning and explains why it was used in the current investigation. Drawing from the insights of Fisher et al. (2019), the selected theory and model furnish invaluable guidance and methodological frameworks for research endeavours, delineating prospective avenues wherein meaningful associations between variables can be elucidated. The theoretical framework articulated herein has been strategically employed to fulfil the study's objectives and holds pivotal significance in informing urban transportation planning practices.

### 2.6.1 Traffic flow theory

Hoogendoorn and Knoop (2013) assert that a comprehensive grasp of traffic flow theory necessitates familiarity with both analytical methodologies, such as shockwave theory and microscopic simulation models, and fundamental traffic flow principles, including road capacity, flow-density relationships, and headway distributions. Ye and Yamamoto (2018) further elaborate that statistical correlations can be discerned among macroscopic traffic flow variables such as flow, density, and velocity. Moreover, urban traffic flow exhibits multifaceted characteristics encompassing periodicity, self-similarity, spatial variability, temporal dynamics, and inherent uncertainty (Lin & Huang, 2021), underscoring the complexity of traffic dynamics.

The prevalence of traffic congestion poses a significant societal and economic challenge in industrialised nations (Olayode et al., 2020). Effectively managing congestion on congested road networks hinges upon a profound understanding of traffic flow principles. This entails discerning the triggers of congestion, identifying factors influencing the onset and propagation of congestion, and comprehending its spatial and temporal dynamics (Alam & Habib, 2021). The current study employs a traffic flow theory framework to clarify the complex relationships between traffic stakeholders, such as vehicle operators, pedestrians, and cyclists, and transportation infrastructure, such as highways and signal control systems. The objective is to describe the relationship between particular traffic actors and the resulting traffic flow phenomena to clarify the fundamental processes controlling urban traffic dynamics.

## 2.7 Quantum Flow Theory (QFT)

### 2.7.1 The concept of quantum flow theory in traffic control

Quantum flow theory seeks to apply elements of quantum mechanics to the complex relationships and uncertainty in traffic through probabilistic models or superposition (Cooper, 2021). Applying the ideas of quantum mechanics, particularly particle flow, to the optimisation and control of traffic systems is the goal of a new concept in traffic control called quantum flow theory (Wang et al., 2021). To understand the traffic flow and congestion of Oxford Street in East London, this theory employs a method that models traffic dynamics by incorporating quantum-like behaviour, specifically probabilistic outcomes and wave-particle duality.

Ofoegbu (2023) defines quantum flow theory in traffic control as a theoretical approach that models and optimises traffic flow using concepts from quantum mechanics, particularly by utilising quantum computing capabilities to solve challenging traffic optimisation problems. Determining the best car routes could improve traffic management by reducing travel times and congestion.

These concepts may be helpful in the current study to model the probability distribution of vehicle speeds or the entangled behaviour of traffic at the three main intersections in the highly complex and dynamic Oxford Street traffic systems in East London. This briefly describes how the current study regulates traffic using quantum flow theory. The elements of QFT in traffic control are described in the section below to provide an overview of how this theory will optimise traffic flow.

### 2.7.2 Elements of quantum flow theory in traffic control

An emerging framework for traffic control is called QFT, which models and optimises traffic flow using concepts from fluid dynamics and quantum mechanics (Bharadwaj & Sreenivasan, 2022). QFT adds wave-like behaviours, probabilistic movement patterns, and non-local interactions among vehicles, unlike classical traffic theories that rely on macroscopic parameters like speed, density, and flow rate (Schwindt, 2022). QFT seeks to improve overall mobility efficiency, decrease congestion, and improve traffic prediction by integrating wave-particle duality and quantum potential (Jaeger, 2018). This innovative approach makes intelligent and self-regulating traffic systems possible, offering a more flexible and dynamic methodology for comprehending intricate transportation networks.

**Wave-particle duality:** According to Hill (2020), depending on the situation, particles like electrons in quantum mechanics can act like waves or like particles. Similar to how each vehicle behaves in traffic, cars can behave like waves when flow and traffic congestion create ripple effects. These vehicle waves can produce patterns in the flow, much like interference patterns in quantum systems. According to the wave-like perspective, traffic behaves like a wave, moving through a medium at steady speeds (Ramadan, 2020). This happens in places like long stretches of road with little to no traffic, where cars flow in a continuous and steady stream. As the wave moves through the lanes, surges (traffic waves that form during peak hour) occur occasionally.

Hale et al. (2016) claim that patterns of traffic interference may be used to characterise circumstances in which automobile movement influences one another, such as when an intersection bottleneck causes congestion downstream. The current study looks at these trends to improve traffic flow by optimising traffic lights, routing, and lane assignments.

**Quantum superposition:** Quantum superposition, which originates in quantum mechanics, is the concept that particles can exist in multiple states concurrently until they are observed or measured (De Ronde, 2018). When metaphorically applied to traffic control, this could imply a system that considers and assesses multiple traffic conditions, routes, or situations in real time, increasing traffic management's effectiveness and dynamic nature in the East London CBD.

*Multiple traffic scenarios at once:* Unlike a standard system that evaluates only one traffic scenario at a time (such as changes in light or vehicle movement), a quantum-inspired system could simultaneously consider all possible traffic flow situations across the three Oxford intersections. This would allow for more rapid and adaptable responses to unanticipated disruptions (like traffic jams or accidents).

*Real-time optimisation:* Using quantum superposition, vehicles may be able to assess multiple routes in real-time and choose the optimal one at any given moment. Considering every possible scenario (traffic congestion, detours, accidents), the system may constantly dynamically update traffic lights, routing software, and other infrastructure to provide the best option. If the system used quantum algorithms to process massive amounts of data from numerous sources (such as traffic cameras, sensors, and GPS data from cars) rapidly, delays and bottlenecks would be reduced. After that, it might suggest new routes or adjust signal timings to help avoid bottlenecks and cut down on delays.

*Predictive traffic management:* By predicting future traffic states based on patterns and external factors like weather or essential events, rather than merely reacting to the current traffic conditions, superposition may allow predictive models that optimise traffic before it becomes a problem.

*Dynamic optimisation:* Traffic lights, for instance, can be adjusted in response to real-time data, allowing them to quantum jump to the optimal cycle after evaluating various potential outcomes, rather than simply following present timings.

Although current systems do not directly use quantum superposition for traffic control, the concept can spur the creation of new, more flexible, efficient, and responsive traffic management techniques by concurrently examining multiple potential outcomes. This could lead to a more intelligent real-time traffic system inspired by quantum technology.

**Quantum tunnelling and traffic flow:** Quantum tunnelling is the process by which particles can move past obstacles that are typically impenetrable (Weber et al., 2023). This could also be used in transportation systems to model situations where traffic seems to tunnel through congested areas despite barriers or bottlenecks. This could demonstrate the ability to manoeuvre through a congested road system, perhaps with detours or algorithms that predict the fastest routes for drivers (Shaygan et al., 2022).

*Alternative routes and predictive systems:* By suggesting less-travelled routes, quantum flow theory may assist systems in identifying less evident routes, improving the overall traffic experience. This is comparable to how particles can tunnel through obstructions.

**Quantum entanglement in traffic networks:** Entanglement is the term used in quantum mechanics to describe particles that become so coupled that one particle's state instantly affects another's state, regardless of their distance (Paneru et al., 2020). This concept could be applied to a traffic system to mimic East London CBD traffic patterns or networked traffic signals. Because the traffic flow at one intersection may be entangled with that of others, enhancing one signal may instantly impact others.

*Coordinated traffic control:* The network as a whole may experience more fluid and seamless traffic movement if traffic lights are designed to function more smoothly in real-time, where the status of one signal promptly notifies the others.

**Optimisation algorithms:** Hussain (2020) asserts that quantum flow theory may employ quantum annealing and other quantum techniques to optimise traffic patterns. Quantum computing may be able to find the best solutions more quickly than classical optimisation techniques, which struggle to handle complex systems with many variables. These could create more efficient traffic light schedules, lane allocations, or routing recommendations.

*Quantum computing and traffic management:* The theory could guide the development of real-time traffic optimisation systems based on quantum technology, allowing for speedier decisions and adjustments, especially in large cities with complex road networks like East London.

## 2.8 Conclusion

In this chapter, an extensive review of the literature on urban planning and transportation management was conducted. A central theme from this analysis is the pervasive issue of traffic congestion, which affects numerous urban areas worldwide. Key contributing factors to this congestion include urban densification, deficient urban roadway infrastructure, widespread reliance on private automobiles, limited road capacity, and deficiencies in public transit systems. These factors have profoundly affected environmental sustainability, public health, and economic vitality.

Concurrently, the economy suffers from productivity losses, increased fuel consumption, and exacerbated traffic delays, which strain individual commuters and broader economic systems. Various strategies have been explored and are under development to mitigate traffic congestion issues. Among these are initiatives to bolster public transportation utilisation, augment roadway capacity, and optimise traffic signalisation schemes. In the context of EL, it is imperative to effectively devise tailored solutions to mitigate traffic congestion and its associated disruptions.

The study underscores the importance of acknowledging the contextual nuances inherent to different urban settings. While solutions such as metro systems or widespread bicycle infrastructure may be effective in specific locales, their applicability to EL and analogous developing regions may be limited due to entrenched automobile-centric cultures and infrastructural constraints.

Consequently, prioritising enhancing public transit networks, particularly bus services, offers a pragmatic pathway to alleviating congestion in EL's Central Business District (CBD) while concurrently fostering a gradual shift away from private vehicle dependence among commuters.

The literature review highlights several key factors contributing to traffic congestion and proposes various strategies for managing it, including introducing Quantum Flow Theory (QFT) as a novel approach. This study's knowledge voids can be summarised below based on the content.

There is a lack of innovative approaches for traffic management. While traditional methods such as enhancing public transport, improving infrastructure, and promoting carpooling have been discussed extensively, there is a limited application of advanced, innovative techniques such as Quantum Flow Theory (QFT) for optimising traffic management.

Quantum mechanics concepts (such as quantum superposition, entanglement, and tunnelling) have not been widely applied to model and control traffic flow. This gap suggests that the study aims to explore and validate how QFT could offer a more dynamic, efficient, and real-time solution to traffic congestion, beyond current optimisation strategies. Most conventional traffic management systems assess one traffic scenario in real-time, frequently responding to the situation. The real-time, multi-scenario analysis suggested by QFT, which evaluates several traffic conditions, routes, and outcomes concurrently to optimise traffic flow dynamically, represents the research gap in this case.

Studies that have already been done on traffic congestion usually concentrate on topics, such as individual carpooling, public transportation, and infrastructure upgrades. This study fills a gap by suggesting the integration of quantum-inspired algorithms to optimise interrelated factors like traffic lights, route selections, and real-time congestion prediction.

The study tackles the problem of maximising traffic flow in highly dynamic and densely populated cities (like Oxford Street in East London), facing more complex traffic patterns and interactions. This contrasts with traffic management strategies frequently used in smaller or less complex urban settings. Applications of quantum computing in traffic control have still not been fully explored. To bridge the gap, this study proposes using quantum computing techniques, such as quantum annealing for complex optimisation, to improve traffic flow management over traditional approaches.

The lack of use of quantum mechanics concepts, especially Quantum Flow Theory, in real-time traffic flow optimisation, is one of the primary gaps in research that this study attempts to fill. Compared to conventional methods, this approach offers a more dynamic and effective way to manage urban traffic by utilising quantum-inspired techniques to concurrently assess multiple traffic situations, optimise traffic signals, and forecast future congestion.

# CHAPTER 3 : RESEARCH METHODOLOGY

## 3.1 Case Study Area: East London CBD, Oxford Street

The Central Business District (CBD) is accessible via a network of paved roads comprising arterial roads, municipal thoroughfares, and streets primarily designated for motorised vehicular traffic. The significant volume of automotive activity within this area has led to observed constraints such as limited parking space, traffic congestion, and heightened levels of air pollution. Moreover, the absence of non-motorised mobility infrastructure, including pedestrian facilities and bicycle lanes, hinders the efficient movement of individuals within the CBD precinct. High levels of congestion are visible, as shown in Figure 3.1. Bottlenecks and capacity restrictions, which frequently serve as the leading causes of congestion, are probably the cause of this congestion. Bottlenecks typically manifest during peak traffic hours when the demand for roadway usage surpasses its inherent capacity. Consequently, a compelling imperative exists to scrutinise the challenges posed by traffic congestion comprehensively and explore avenues for their mitigation. Moreover, the application of quantum flow theory stands poised as a prospective avenue for revitalising the urban core, enhancing its functional efficacy and sustainable mobility.

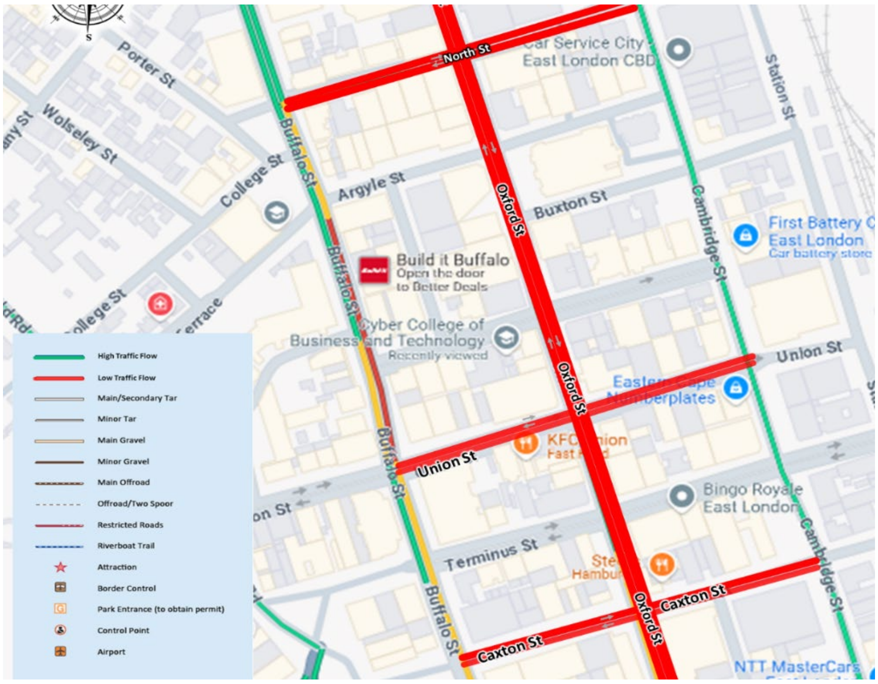


**Figure 3. 1: Google Earth @2023 AfriGIS (Pty) Ltd**

## 3.2 Research Methodology Outline

This chapter delineates the research methodology employed for data collection and analysis within the current study. Commencing with a delineation of the research approach, a quantitative methodology is pursued. This section elaborates on the data collection techniques, the sampling methodology used to target the study population, and the data analysis techniques leveraged throughout the study. Furthermore, the chapter culminates with an exploration of ethical considerations, an acknowledgement of study limitations, and a discussion on ensuring credibility and trustworthiness in the execution of the survey study. Ultimately, the primary objective of this chapter is to establish a clear framework for the study's direction, aligning with the aims and objectives articulated in Chapter One.

## 3.3 Research Approach

The present investigation followed a quantitative research design emphasising the objective measurement and statistical, mathematical, and numerical analysis of information obtained from surveys and questionnaires. The methodical gathering and quantitative data analysis are integral components of quantitative research (Hu, 2020). This methodology was chosen to target numerical data acquisition and subsequent generalisation across various demographic groups, facilitating a comprehensive understanding of traffic congestion. Various non-textual formats, such as tables, charts, and figures, were extensively utilised to present the acquired information. These formats effectively organised and visualised the data, enhancing its accessibility and interpretability for the reader.

## 3.4 Data Collection

As posited by Asenahabi (2019), data collection denotes a systematic process to acquire and quantify information about the variables of interest, thereby facilitating the investigation of stated research questions, hypothesis testing, and result assessment within a research study. Researchers must exercise caution during data-gathering, as incomplete data may lead to erroneous findings and conclusions (Talari and Goyal, 2020).

Various types of data sources can be harnessed for data collection. Kumar (2014) elucidates that primary and secondary sources serve as repositories for data encompassing situational, demographic, issue-related, and phenomenological aspects. As depicted in Figure 3.2, both primary and secondary data collection techniques were deployed within the framework of the current study.

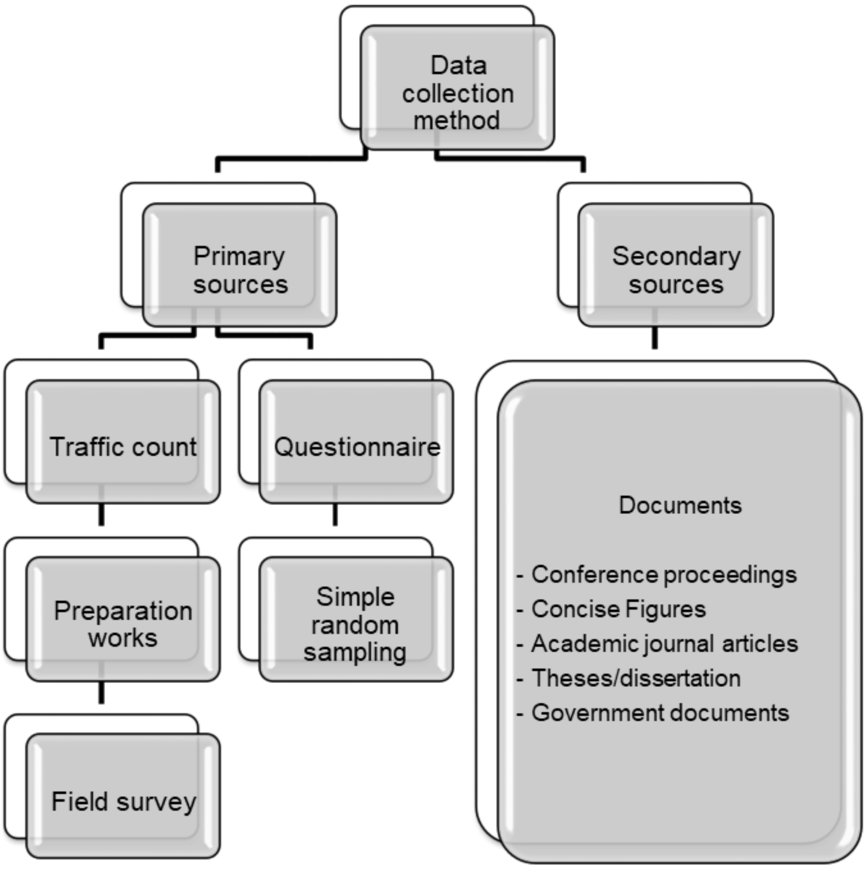


**Figure 3. 2: Data collection methods**

### 3.4.1 Primary data sources

Data obtained from primary sources refers to information not previously compiled or published elsewhere. Primary data collection methods are surveys, interviews, and observations (Kumar, 2014). The present study gathered fundamental data using a manual traffic count and a questionnaire.

The acquisition of new information from primary sources involved the administration of questionnaires and traffic surveys, aimed at addressing specific research inquiries and acquiring primary data. The questionnaire served as a means for researchers to solicit the perspectives of drivers and commuters regarding the phenomenon of traffic congestion. Criteria such as the intersection's significance, proximity to the Central Business District (CBD), impact on urban activities, traffic volume, flow patterns, congestion levels, and safety considerations were instrumental in selecting three intersections along Oxford Street. Traffic surveys were conducted at the following intersections based on Caxton Street, Union Street, and North Street parameters.

**Questionnaire:** A questionnaire constitutes a structured document containing a series of inquiries tailored to a statistically significant number of respondents, serving as a fundamental tool for data collection in surveys (Stantcheva, 2023). It is adeptly utilised for the acquisition of demographic information and the discernment of public opinion. The questionnaire assumed a pivotal role in this study, as previously delineated. Comprising sections encompassing demographic details, a five-point Likert scale ranging from 1=Strongly Disagree to Agree 5=Strongly, and an array of closed-ended queries provided a comprehensive data collection framework. Respondents were allowed to select or rank the most pertinent response(s) according to their perspectives.

Furthermore, the questionnaire's introductory statement incorporated an invitation to participate and a consent form for survey participants, ensuring ethical compliance and voluntary participation. The surveys were disseminated to commuters and drivers along Oxford Street by the researcher(s) employing a simple random selection methodology. Distribution was orchestrated to reach a predetermined sample size of 384 respondents, calculated for statistical robustness. Additionally, to accommodate respondents with limited literacy levels, researchers were prepared to offer assistance by reading and elucidating the questionnaire's contents as needed, thereby ensuring comprehension and inclusivity in the data collection process.

**Manual traffic count:** The manual traffic count method was deployed to ascertain the traffic volume across the three distinct intersections along Oxford Street, with the primary objective of garnering situational insights through direct observation. To bolster the precision of the counting process, a team of four personnel per intersection was engaged to tally the number of vehicles traversing each lane meticulously. Tally sheets were the primary tool for documenting traffic count data, ensuring methodical recording. The traffic count endeavour spanned the entirety of the week, from Monday to Sunday, encompassing 16-hour observation periods daily, commencing at 6:00 and concluding at 22:00, across the designated intersections. Special attention was accorded to peak traffic hours, with corresponding data meticulously recorded during the traffic count operations. Traffic volume data was categorised according to various travel modes, including but not limited to cars, motorcycles, trucks, buses, trucks with trailers, and taxis, thus facilitating a comprehensive understanding of vehicular composition within the studied intersections.

### 3.4.2 Secondary data sources

The classification of secondary sources encompasses various forms of pre-existing data, such as archived traffic counts, conference proceedings, statistical summaries, academic journal articles, published books, newspapers, theses, dissertations, and governmental publications (Struwig and Stead, 2013). These sources serve as valuable reservoirs of contemporary information, facilitating the categorisation of current data. In the context of the present study, the researcher conducted a comprehensive literature review to delve into the intricacies of road traffic congestion. This endeavour involved sourcing information from academic journal articles, official reports, and recommended literature. By synthesising insights from these secondary sources, the researcher cultivated a nuanced understanding of the subject matter, thereby enriching the depth and breadth of the study's investigation.

### 3.5 Sampling of the Population Technique

Seenivasan (2020) elucidates that sampling methodology serves as a pragmatic solution when researching the entire population, which is impractical due to various constraints such as the complexity of the research problem, budgetary limitations, and temporal constraints. Upon delineating the research strategy, it becomes imperative for the researcher to delineate the target demographic for data collection (Groenland and Dana, 2020). In the context of this investigation, which involves a sizable population that is not amenable to simultaneous research, a systematic survey of road users was undertaken at strategic nodes within East London (EL). The subsequent section elucidates the overarching process employed to select a representative sample from the target population, ensuring methodological rigour and validity in the sampling procedure.

#### 3.5.1 Simple random sampling

According to Bryman and Bell (2014), the simplest type of probability sampling technique is the simple random sample, which guarantees that every member of the population has an equal chance of being selected for the sample. This approach epitomises fairness, offering every population an equitable chance of selection (Sharma, 2017). While various sampling methods are available to researchers, the current study opted for a simple random sampling method, driven by the objective of affording each individual an equal likelihood of inclusion in the sample. This methodology was chosen to uphold the principle of fairness and ensure that the study's variables are accurately and impartially represented. In line with this sampling approach, questionnaires were disseminated to a sample comprising 384 respondents over the study period, fostering a representative and statistically robust dataset.

A population proportion (P) of 50% is used in sample size determination for the current study because it represents the most conservative estimate, ensuring the maximum possible sample size for a given confidence level and margin of error.

Variability is maximised by a simple method of random sampling. The degree of variation within a population is variability in statistical sampling. Responses are equally distributed between the two possible outcomes because it assumes the most significant uncertainty or variability. P = 50% (or 0.5) is selected because it produces the most statistically rigorous and dependable sample size (Anderson et al., 2017).

Sampling bias is reduced by using a simple method of random sampling. Researchers reduce the possibility of underestimating the necessary number of participants by taking a cautious approach to sample size determination by assuming P = 50% (Anderson et al., 2017). As a result, the sample is more likely to be representative and statistically valid. Because it yields the largest and safest sample size estimate, P = 50% was chosen to ensure that the research findings are unbiased, representative, and robust.

### 3.5.2 Survey sample size

A simple random sample must be large enough to minimise biases or sampling errors and guarantee the generalisability of results from the sample. Not only is the percentage of the research population sampled important in this case, but also the sample size in absolute terms about the population's complexity, the researcher's goals, and the statistical techniques used for data analysis (Taherdoost, 2016). To be succinct, larger sample sizes diminish sampling error, albeit at a diminishing rate. The following statistical formulas were employed to determine the sample size required for the population of East London (EL). Numerous methodologies exist, each encompassing distinct formulas, for calculating the sample size, particularly for categorical data.

$$nn_o = \left(\frac{p(1-p)Z^2}{E^2}\right) \quad 3.1$$

Where:

- $nn_0$ - is the required sample size
- P - is the percentage occurrence of a state or condition
- E - is the maximum percentage error required
- Z - is the value corresponding to the level of confidence required
- N - is the population size
- n - is the final sample size

In this study, the following sample size from the EL population was calculated using the following formula(s) and standards:

- Z value = 1,96
- Level of confidence = 95%
- Variation of the population (P) = 50% (0,5)
- Margin of error (E) = 5% (0,005)
- Population size (N) = 463 651

$$nn_0 = \frac{p(100-p)Z^2}{E^2}$$

$$nn_0 = \frac{0.5(1-0.5)1.96^2}{0.05^2}$$

$$\underline{\boldsymbol{nn_0 = 384}}$$

$$n = \frac{nn_0}{1+\frac{n_0}{N}}$$

$$n = \frac{384}{1+\frac{384}{463\ 651}}$$

**n = 384**

$$n_0 = \frac{p(100-p)Z^2}{E^2}$$

$$n_0 = \frac{0.5(1-0.5)1.96^2}{0.05^2}$$

$$\underline{\boldsymbol{n_0 = 384}}$$

$$n = \frac{n_0}{1+\frac{n_0}{N}}$$

$$n = \frac{384}{1+\frac{384}{463\ 651}}$$

**n = 384**

## 3.6 Data Analysis

As Kauffmann et al. (2020) expounded, data analysis encompasses systematically examining datasets to extract pertinent information to inform decision-making and substantiate conclusions. Following data collection, meticulous organisation and analysis procedures were undertaken. Specifically, the Statistical Package for the Social Sciences (SPSS) software was utilised to analyse the data gleaned from the closed-ended questions embedded within the questionnaire. Within the framework of this study, descriptive statistical analysis was adopted as the principal analytical approach. Descriptive statistical analysis involves the elucidation and summary of key features of the dataset, facilitating a comprehensive understanding of the underlying patterns and trends. Further elucidation on the methodology and intricacies of descriptive statistical analysis will be provided.

### 3.6.1 Descriptive statistics analysis

According to Struwig and Stead (2013) and Van Zyl (2014), the kind of statistical analysis that yields statistical summaries of data is known as descriptive statistics. Bickel and Lehmann (2012) state that descriptive statistics interpret the data to highlight the mean and standard deviation, two critical aspects of the researcher's score distribution. The researcher used descriptive statistics to comprehend and summarise the numerical characteristics of the dataset (Christensen et al., 2015).

The descriptive statistics method of analysis was employed to analyse the collected data. According to Loeb et al. (2017), descriptive statistics are numerical summaries of data explaining the events in the sample. Pie charts and bar graphs were used to illustrate the data once frequency Tables were created. The ability of descriptive statistics to modify, reorganise, and order data to produce descriptive information was tested. The goal was to turn raw data into a simple, understandable, and interpretable format.

### 3.7 Ethical Consideration

The study process necessitates careful consideration of a broad spectrum of ethical considerations (Creswell, 2014). Ethics pertains to the moral principles and methodologies governing the conduct of individuals, communities, or groups, guiding decisions and behaviours in alignment with established standards (Blumberg et al., 2014). Ethical principles are benchmarks for appropriate conduct, encompassing fundamental values and practices. In conducting the study, the researcher diligently addressed ethical concerns related to human rights, including but not limited to the right to anonymity, confidentiality, informed consent, privacy protection, avoidance of deception, and prevention of harm to participants.

Throughout the research process, adherence to ethical standards was paramount, guided by the policies and protocols established by the Central University of Technology, Free State, governing the involvement of human subjects in research endeavours. These ethical considerations were rigorously upheld to ensure the integrity and welfare of all participants involved in the study.

#### 3.7.1 Permission

To ensure the legitimacy and ethical integrity of the present study, the researcher sought formal approval by applying for ethical clearance to the Faculty of Engineering, the Built Environment, and Information Technology at the Central University of Technology, Free State. This process involved obtaining written authorisation from the appropriate institutional body, confirming adherence to established ethical guidelines and protocols governing research involving human subjects.

#### 3.7.2 Confidentiality and privacy

Confidentiality entails carefully handling respondents' information to preserve their privacy and secrecy. Throughout the study, stringent measures were implemented to safeguard participants' identities and maintain the confidentiality of their responses. Central to this aspect is the principle of trust, wherein the researcher assures participants that their privacy will be upheld, and their information will not be exploited for the researcher's gain or advantage. This commitment involved refraining from deception or betrayal of participants' trust during the research process and in disseminating results.

### 3.7.3 Voluntary participation and consent form

The respondents were duly informed about the significance of voluntary participation and their autonomy to withdraw from the study at any juncture. The concept of informed consent was thoroughly elucidated to the survey respondents, both verbally and through written documentation appended to the questionnaires. Adherence to these principles necessitated providing participants with comprehensive information regarding the research process and its objectives. Subsequently, participants were invited to complete the questionnaire, wherein they were required to acknowledge their understanding and consent by signing the research study information and consent form. This formal agreement signified their willingness to participate in the study, and the completed forms were tendered to the researcher upon mutual agreement.

## 3.8 Ensuring Credibility and Trustworthiness

This section succinctly outlines the strategies employed to uphold credibility and trustworthiness in research. Credibility and trustworthiness are essential for fostering confidence and trust within the scientific community (Chatzimparmpas et al., 2020).

### 3.8.1 Credibility

As per Rose and Johnson (2020), credibility pertains to the extent to which participants perceive the study results as accurate and believable. This notion stems from the imperative to establish a direct linkage between the study's findings and reality, demonstrating their accuracy. Before publication, researchers often corroborate their findings with participants to ensure alignment with their perspectives, as Snow (2018) highlighted.

In the present study, credibility was bolstered through the researcher's distribution of questionnaires, underscoring a commitment to direct engagement with participants. Furthermore, the researcher availed themselves of a research methodology workshop conducted by the Central University of Technology, Free

State, as a preparatory measure. The study's credibility was further reinforced by the deliberate selection of drivers and commuters directly impacted by issues related to traffic congestion. The subsequent section elucidates the concept of trustworthiness within the context of this study.

### 3.8.2 Trustworthiness

In quantitative research, trustworthiness is a paramount criterion for evaluating the quality of a study. As articulated by Chard and Tovin (2018), trustworthiness encompasses several facets, including truth value, applicability, consistency, and neutrality, all of which contribute to the robustness of a study's findings. To ensure credibility, the researcher employed many strategies before and during the research process. One such strategy involved fostering long-term engagement, wherein the research questionnaire was meticulously described, and ample time was devoted to interacting with participants and delving into the data. This approach (Hines et al., 2022) facilitated the establishment of trust and mutual understanding regarding the intricacies of traffic dynamics and background context, thereby enhancing the credibility and dependability of the study's findings.

## 3.9 Conclusion

This chapter delves into the intricacies of the research methodology adopted in the study. A comprehensive overview of the applied method, encompassing the execution stages and procedural steps, is presented herein. Emphasis is placed on elucidating the research methodology procedures, including data collection, population sampling, and data analysis methodologies employed in the study. The main instrument used to gather data was a questionnaire, which made it easier to obtain the results and gain a deeper understanding of the topic. The questionnaire distribution adhered to simple random sampling principles, with a calculated sample size of 384 participants drawn from the population. Furthermore, the chapter delineates the meticulous calculation of vehicle traffic volume along Oxford Street's three major intersections daily, from Monday to Sunday, between 6:00 and 22:00.

The following two chapters, four and five, deliver the research findings in great detail and explain how they were interpreted, respectively.

# CHAPTER 4 : QUANTITATIVE DATA ANALYSIS, FINDINGS AND INTERPRETATION

## 4.1 Introduction

The primary objective of this study was to conduct a comprehensive analysis of traffic capacity and optimise traffic flow to facilitate safe mobility along Oxford Street within the EL-CBD, employing quantum flow theory at three pivotal intersections. The overarching goal was to devise effective strategies for mitigating traffic congestion on Oxford Street.

This chapter aims to provide the quantitative results regarding traffic congestion on Oxford Street. As detailed in Chapter Three, the study adopted a quantitative research methodology, employing a questionnaire for data collection. The questionnaire targeted both vehicle drivers and commuters who regularly traverse Oxford Street. A simple random sampling method was used to distribute 384 questionnaires in total. The questionnaires were then returned to the researcher after the respondents had completed them. The questionnaire aimed to get participants' thoughts and experiences about traffic congestion. Also, the traffic count was used to quantify several vehicles.

The collected data underwent coding and analysis utilising the IBM SPSS Statistics (Version 22) software. Analysis techniques included percentage calculations, frequency distributions, and descriptive studies. The insights gleaned from this analysis were utilised to formulate an optimised route assignment network design to enhance safe mobility and operational efficiency, leveraging principles of quantum flow theory.

To enable the study to accomplish its aim, the following research objectives were formulated:

- Utilising quantum flow theory, the aim is to discern the root causes of congestion and delays at major intersections along Oxford Street, subsequently analysing the collected data. This analysis will be the foundation for devising an optimised route assignment network design to enhance mobility's safety and efficiency. The outcomes of this objective are detailed in sections 4.3.3, 4.3.4, and 4.3.5.

- The objective entails the development of a proposed Integrated Transportation Plan (ITP) leveraging the quantum flow traffic method, based on the data from Oxford Street. This plan aims to augment clever city design by incorporating alternative charter preferences. The recommendations from this objective are presented in sections 5.4.6 and 5.4.9 of the report.

## 4.2 Demographic Profile of Oxford Street Road Users

This section furnishes demographic insights about Oxford Street Road users, encompassing gender, age group, duration of residence in EL, and occupation status. These data were collected through Section A of the questionnaire, which is designated as biodata. The outcomes are delineated in sections 4.2.1 to 4.2.4 herein. A visual representation of the demographic profile of Oxford Street Road users is depicted in Figure 4.1 for elucidation.

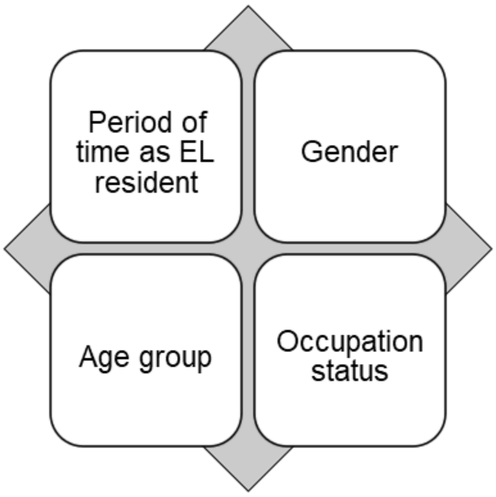


**Figure 4. 1: The framework of the demographic profile**

The following section provides the outcomes based on how long the responders have been residing in EL, which is the first question in the questionnaire.

### 4.2.1 Impact of residency duration on perceptions of congestion in EL

In evaluating the extent of traffic congestion along EL's Oxford Street, the duration of respondents' residency in the area assumes paramount importance. The perspectives of individuals with prolonged exposure to traffic-congested locales are indispensable, as their insights can inform decision-making processes and facilitate the formulation of pragmatic policies (Rajé et al., 2018). Figure 4.2 presents the distribution of participants based on their length of stay in EL, offering valuable insights into the correlation between residency duration and perceptions of traffic congestion.

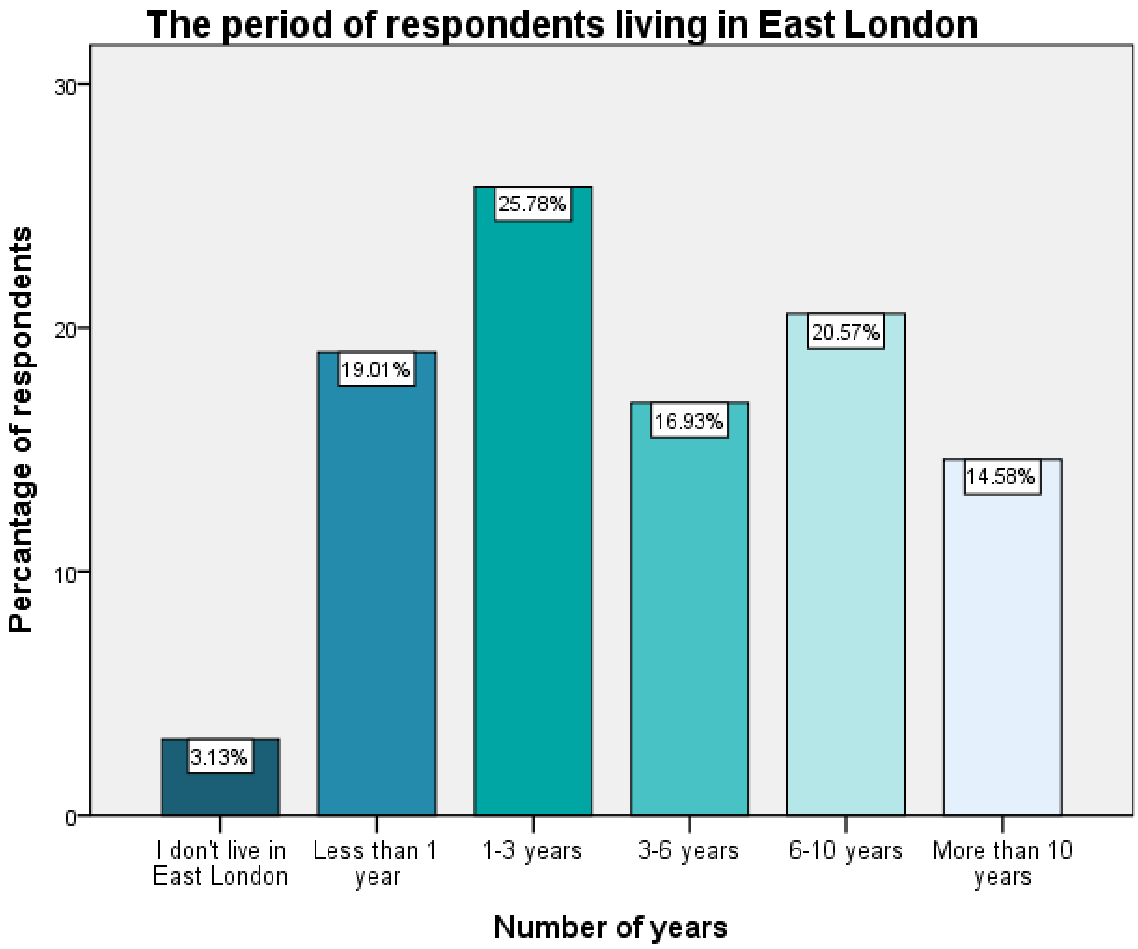


**Figure 4. 2: Indication of the period respondents stayed in EL**

The respondents residing in EL for 1-3 years constituted the majority, comprising 25.78% of the sample, followed by those living for 6-10 years at 20.57%, individuals with less than 1 year of residency at 19.01%, and those with 3-6 years of residency at 16.93%. Additionally, respondents with over 10 years of residency accounted for 14.58% of the sample, while individuals not permanently residing in EL constituted 3.13% of respondents. Subsequent sections will delineate the distribution of respondents by gender.

### 4.2.2 Gender

Gender plays a pivotal role in vehicle operation and ownership, with implications for traffic dynamics on Oxford Street. Including gender responses aims to discern potential behavioural disparities contributing to congestion. Research suggests that female road users typically exhibit greater caution, undertake more trips, and rely on televised traffic information to navigate less congested routes (Ison & Rye, 2003). Conversely, male drivers tend to have higher road exposure and are more prone to speeding, traffic violations, and substance use, factors that can precipitate accidents and subsequent traffic congestion (Cordellieri et al., 2016).

Under section A, biodata, in question two of the questionnaire, the question of gender was posed. The respondents' gender differences are seen in Figure 4.3.

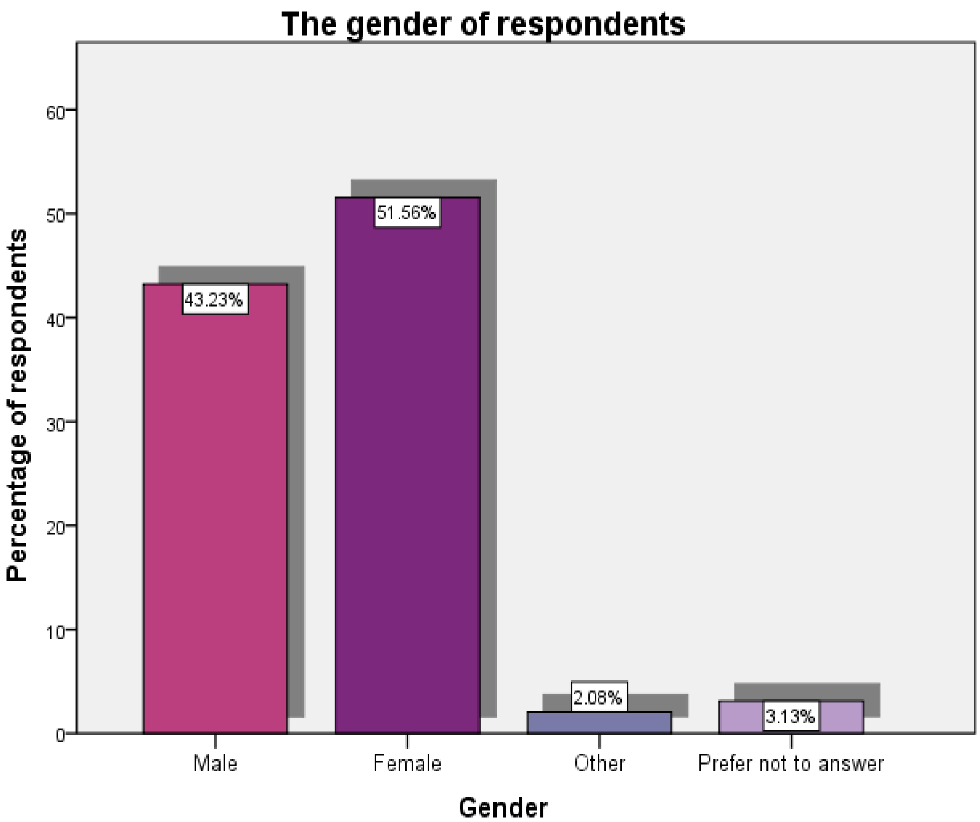


**Figure 4. 3: The indication of the gender of respondents**

A total of 384 participants answered this question. Of the total, 51.56% were female, 43.23% were male, 2.1% chose ‘other’, and 3.1% preferred not to answer. The percentages for the age groups of the respondents are shown in the following section.

### 4.2.3 Age group

The respondents in this study spanned an age range from under 18 to 55 and above, encompassing various age cohorts. Age group delineation assumes significance in addressing the traffic congestion phenomenon. Research indicates that young drivers often exhibit tendencies towards inexperience and driver distraction, while senior drivers tend to adopt a more cautious approach with slower mean speeds (Rolison et al., 2018). Moreover, young drivers are notably more prone to causing accidents due to misinterpretation of road signs and failure to adhere to traffic signals (Zahid et al., 2020). Figure 4.4 depicts the age distribution of participants utilising Oxford Street.

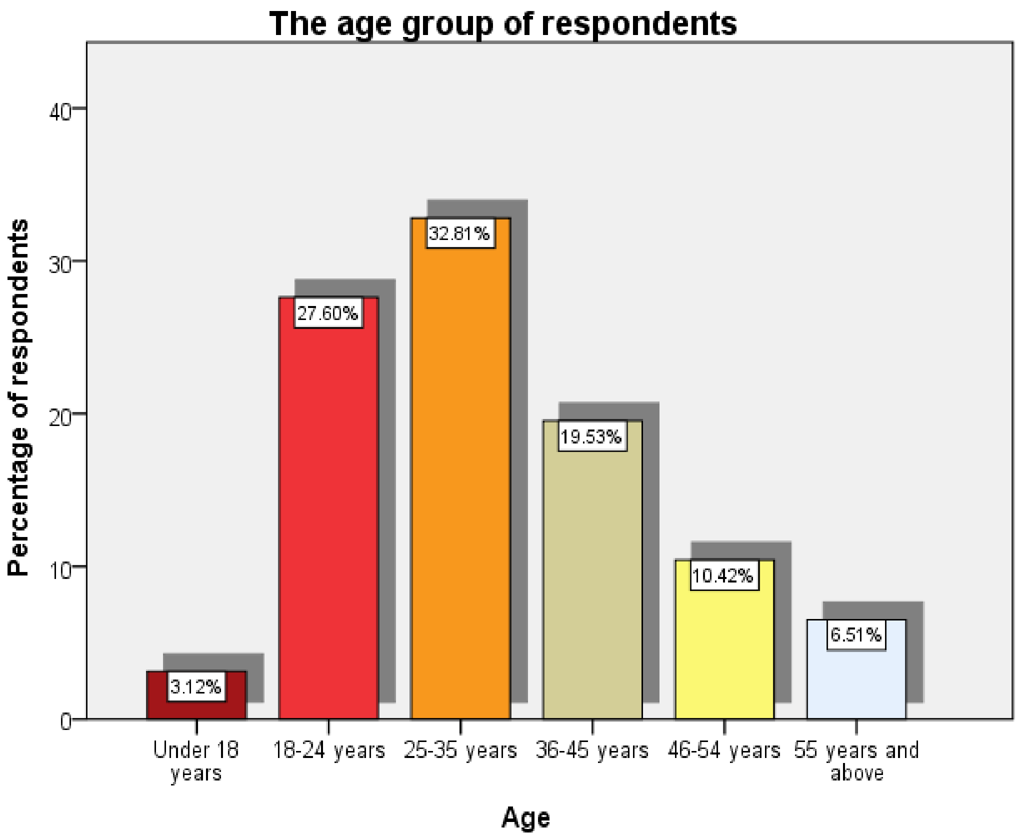


**Figure 4. 4: Indication of the age groups of the respondents**

Participants were requested to specify their age category from the following options: under 18, 18-24, 25-35, 36-45, 46-54, 55 years and above, with an additional option for those opting not to disclose. The predominant age category among respondents fell within the range of 25-35 years, constituting the most significant percentage at 32.8%, followed by the 18-24 age bracket at 27.6%. Furthermore, 19.5% of respondents belonged to the 36-45 age group, while 10.4% were aged 46-54. Individuals aged 55 and above comprised 6.4% of the respondents, whereas those under 18 accounted for 3.1%. Including age-related survey questions proved instrumental in capturing the diverse life experiences, evolving preferences, and behaviours across different age cohorts. Subsequent sections will delineate the distribution of respondents by occupation status.

### 4.2.4 Occupation status

The employment status section was categorised into four groups: employed, self-employed, unemployed, and student. Heightened traffic congestion can diminish commercial enterprise productivity, escalate operating costs and constrict market coverage for individual firm sites. Figure 4.5 illustrates the current employment status of the study participants.

It should be noted that, in the distributed questionnaire, drivers were categorised under the broader classification of employed. This approach was taken with careful consideration of respondent comfort and data reliability. The researcher acknowledges that individuals may sometimes be hesitant or uncomfortable disclosing specific details about their occupation, particularly in a survey setting. To encourage participation and ensure accurate responses, the questionnaire was designed to group drivers under employed, rather than explicitly identifying them as a separate category.

As a result of this classification strategy, the exact number of drivers who participated in the survey through the questionnaire could not be directly extracted. However, this does not diminish the study's validity, as the overall representation of road users, including drivers, was still captured within the surveyed sample. The primary objective was to collect meaningful and honest responses without discomforting the participants, possibly leading to incomplete or inaccurate data.

By structuring the questionnaire in this manner, the study sought to balance data accuracy with ethical considerations, ensuring that respondents felt at ease while maintaining the integrity of the research findings.

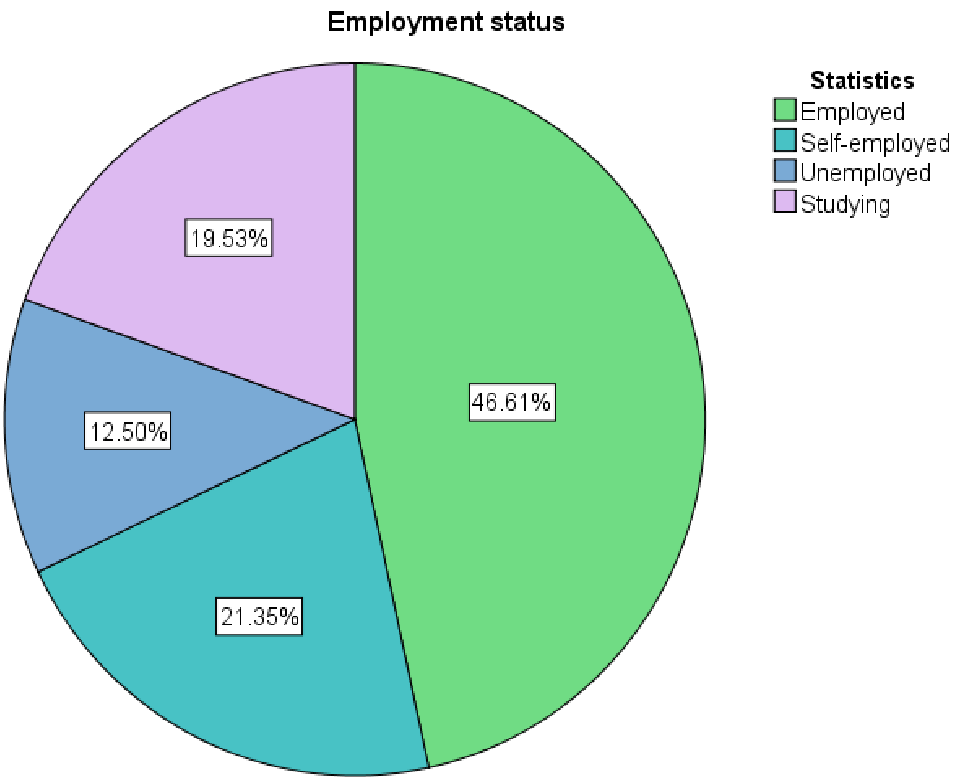


**Figure 4. 5: Indication of the occupation status of respondents**

As depicted in Figure 4.5, the highest proportion (46.61%) of respondents comprised company employees from the public and private sectors. Business owners or self-employed individuals accounted for 21.4% of responses, while students constituted 19.5%, and unemployed respondents comprised 12.5%. These findings align with previous traffic studies, identifying employment patterns as a significant contributor to traffic congestion (Anciaes et al., 2017). Notably, the predominant percentage of company employees (46.6%), followed by self-employed individuals (21.4%), underscores the trend of individuals migrating from rural areas to the EL to pursue employment opportunities. This trend is further fuelled by economic growth, contributing to the escalating trend of car ownership.

The concentration of workers in urban areas strains transportation systems and stimulates economic development (Rajé et al., 2018). Consequently, traffic congestion emerges as a prominent challenge in metropolitan areas globally, driven by the exponential rise in car ownership and travel demand.

## 4.3 Descriptive Statistics for Traffic Congestion

A descriptive analysis facilitates a deeper consideration of the forthcoming sections' data. Descriptive statistics succinctly summarise the data, offering valuable insights into respondents' responses to key inquiries (Ross, 2014). The variables utilised stem from Section B, specifically questions eight to 16, within the traffic condition survey outlined in the questionnaire (refer to Appendix B). Employing a five-point Likert-type scale, the questionnaire aimed to elicit responses from participants. To enhance interpretation, items on the questionnaire were categorised into three groups. As a result, the neutral category was left intact, but ratings like "agree" and "strongly agree," as well as "disagree" and "strongly disagree," were combined into a single classification.

The ensuing sections present the outcomes of the analysis, categorised as follows:

- i Mobility of passengers
- ii Exploration of low traffic flow by respondents
- iii Uncertainties influencing transportation system performance iv Peak period analysis v Measures of traffic congestion

Figure 4.6 offers a graphical representation of descriptive statistics about traffic congestion.

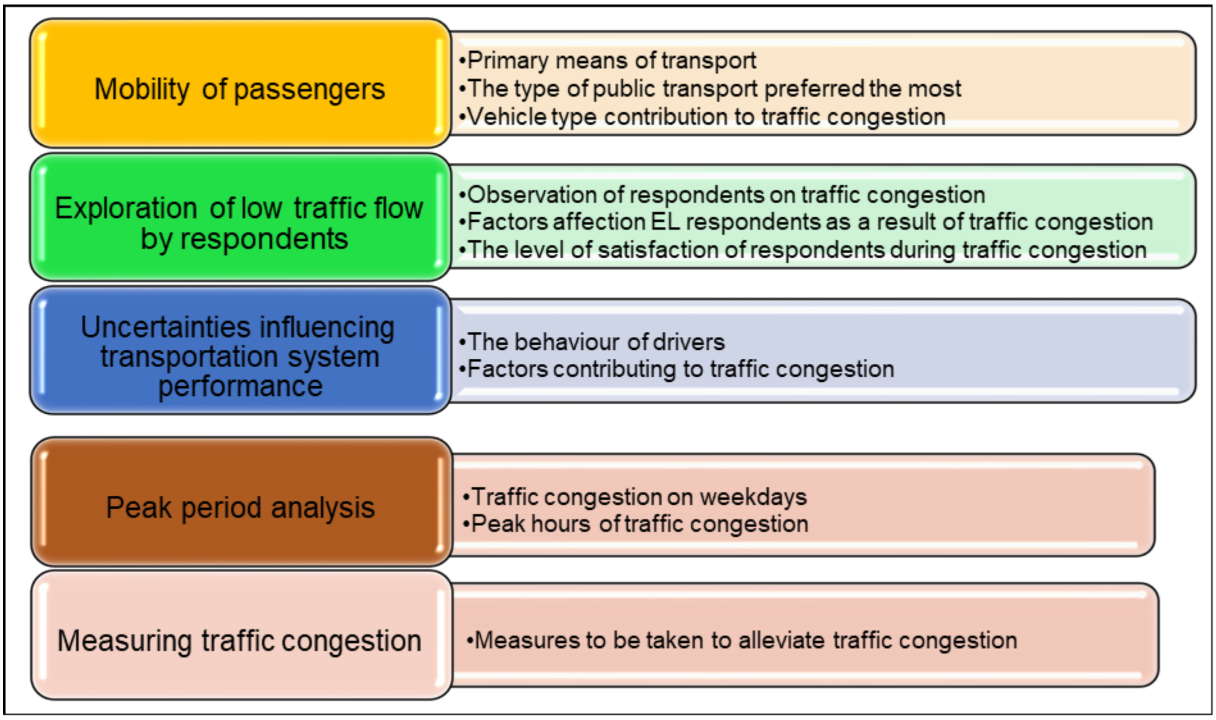


**Figure 4. 6: The framework of the descriptive statistics analysis**

### 4.3.1 Overview of mobility in East London

Passenger mobility encompasses the movement of individuals utilising various modes of transportation, including motorised and non-motorised vehicles, as well as collective and individual means (Camilleri, 2020). In the context of EL, mobility serves as a vital economic catalyst, facilitating essential activities and underpinning the functionality of society. Enhancing the efficiency and quality of mobility infrastructure within a country fosters economic growth and elevates the standard of living for its populace (Ness, 2008).

Under the purview of passenger mobility, the following results are outlined: primary means of transportation, preferred public transportation (PT) utilised by respondents, and vehicle types contributing to traffic congestion in EL. These findings shed light on the dynamics shaping passenger mobility within the region.

Since a greater reliance on private vehicles can worsen traffic, air pollution, and environmental degradation, this emphasises the necessity of urban planning and policy interventions concentrating on enhancing public transportation systems.

According to the survey, public transport is not advanced enough to satisfy the needs of the expanding population of East London.

**The primary means of transport:** Various transportation modes exist, categorised based on infrastructure requirements, transportation modes, or service provision. In South Africa (SA), the predominant cause of excessive car ownership is the inadequacy of public transportation (PT) infrastructure. This deficiency compels individuals to rely heavily on private vehicles for mobility. Notably, the global trend of escalating car ownership is expected to be particularly pronounced in developing nations like SA. Figure 4.7 illustrates the primary means of transportation utilised by participants, offering insights into prevailing mobility patterns.

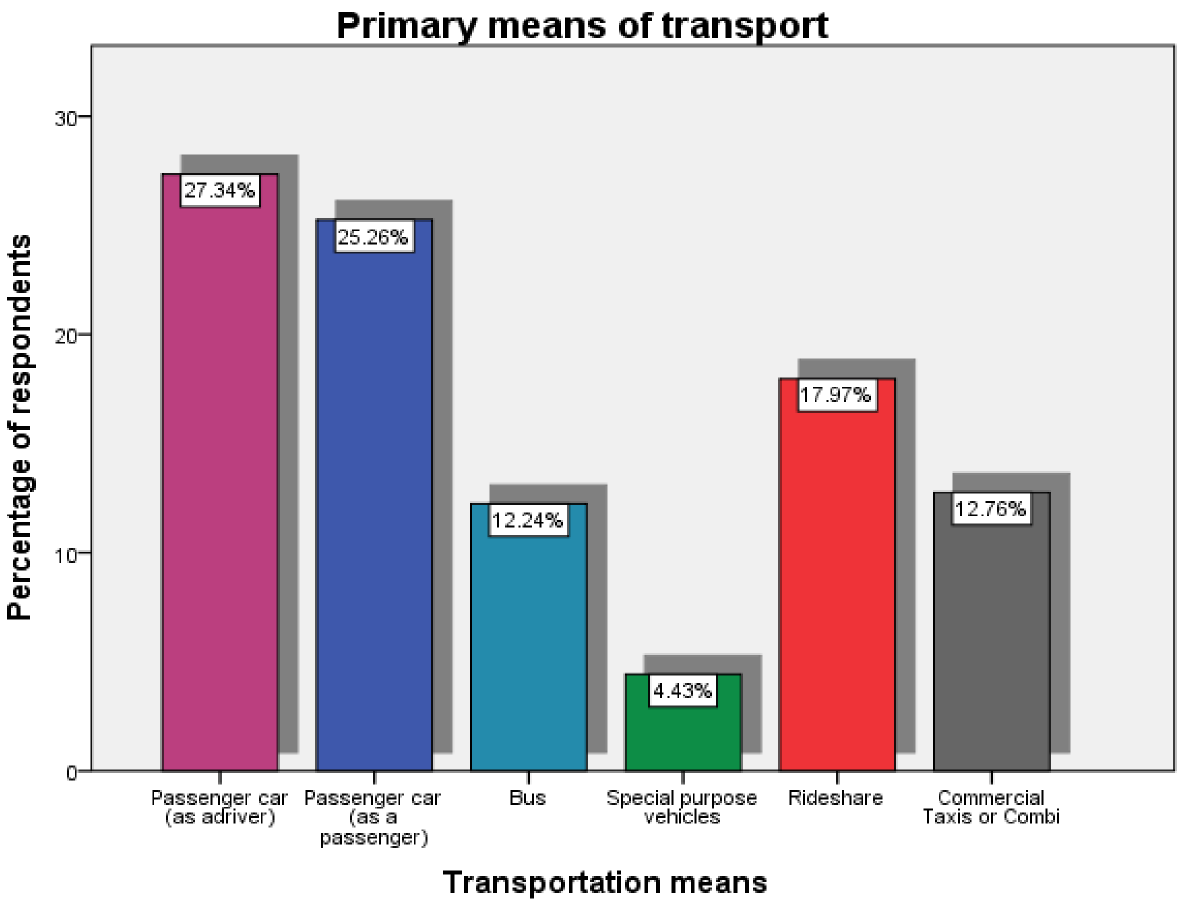


**Figure 4. 7: The primary means of transport**

The survey findings reveal that 27.3% of participants utilise passenger cars as drivers, while 25.3% opt for passenger cars as passengers. Additionally, 18% use rideshare services, 12.8% utilise taxis, 12.2% rely on buses, and 4.4% utilise special purpose vehicles. These results underscore a significant reliance on personal vehicle ownership and usage among respondents, indicative of the notable increase in car ownership fueled by EL's rapid economic expansion.

Conversely, dissatisfaction with public transportation is evident among passengers, coinciding with a decline in their expectations of privacy (Ababio-Donkor et al., 2020). Suman and Bolia (2019) argue that public transportation struggles to compete with private automobiles in meeting passengers' privacy expectations, often falling short in-service delivery. The most utilised or preferred type of public transportation by participants will be elucidated below.

**Preferred public transport options in East London:** Public transportation (PT) is pivotal in facilitating efficient traffic flow on roads, yet it often faces challenges, particularly in urban settings (Leonard et al., 2020; Luke & Heyns, 2020; Mamabolo & Sebola, 2018). Nonetheless, several countries have endeavoured to enhance access to PT services by implementing restrictions on using private vehicles within neighbourhoods (Mulley & Kronsell, 2018; Oeschger et al., 2020). Figure 4.8 presents the outcomes regarding the most preferred PT options in EL, per respondents' preferences.

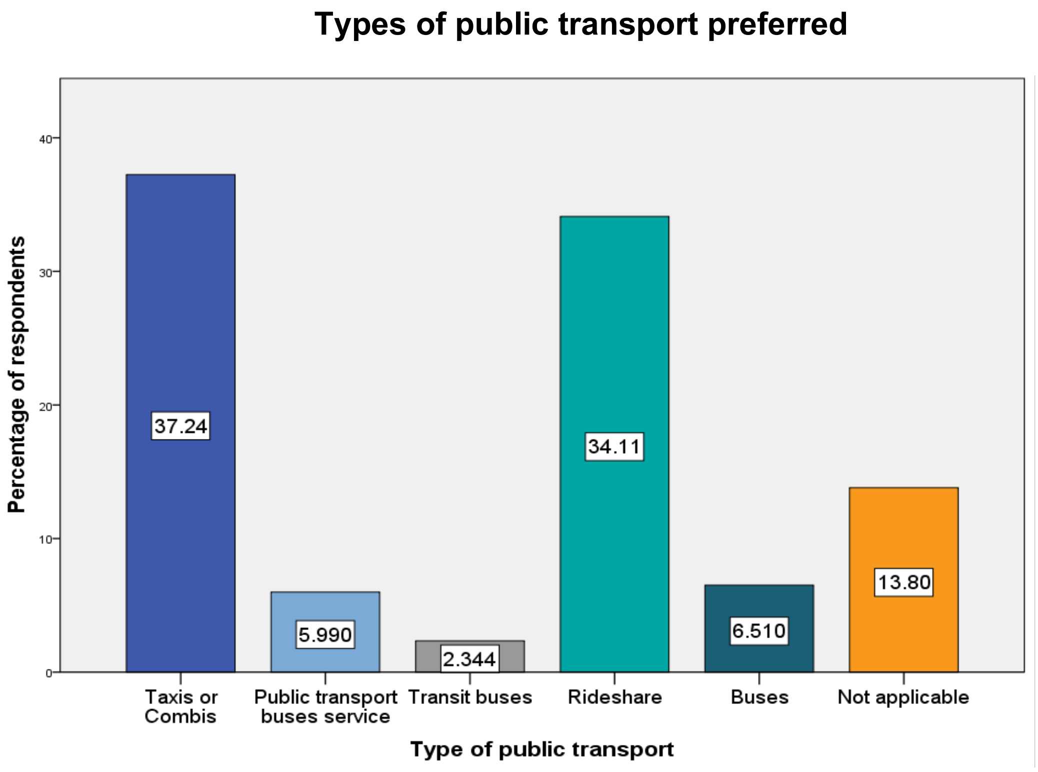


**Figure 4. 8: The types of public transport preferred**

The survey results indicate that 37.2% of respondents prefer taxi or combi services, while 34.1% opt for rideshare options. Additionally, 6.5% utilise buses, 6% rely on public transportation bus services, and 2.3% utilise transit buses. Interestingly, 13.8% of respondents prefer none of the specified public transportation options. The predominance of taxi usage among respondents suggests that improvements in the taxi industry's operations, behaviour, and culture could attract more commuters.

However, the country's inadequate road infrastructure hinders the socio-economic benefits of mobility in South Africa (Sewell et al., 2019). It is noteworthy that buses are rarely utilised in the EL city due to the insufficient road system, which does not support bus operations. The proliferation of substandard, inaccessible, and segregated infrastructure, as highlighted by Allen et al. (2021), exacerbates poverty levels. Many communities remain underserved as public transit fails to adequately connect them to their destinations, primarily due to poor road conditions incompatible with bus operations. Consequently, these commuters seldom utilise or prefer buses.

**Impact of vehicle types on traffic congestion:** Passenger, commercial, and special-purpose vehicles formed part of this question, which was addressed to participants. Figure 4.9 demonstrates the respondents' opinions on which type of vehicle contributes to traffic congestion on Oxford Street.

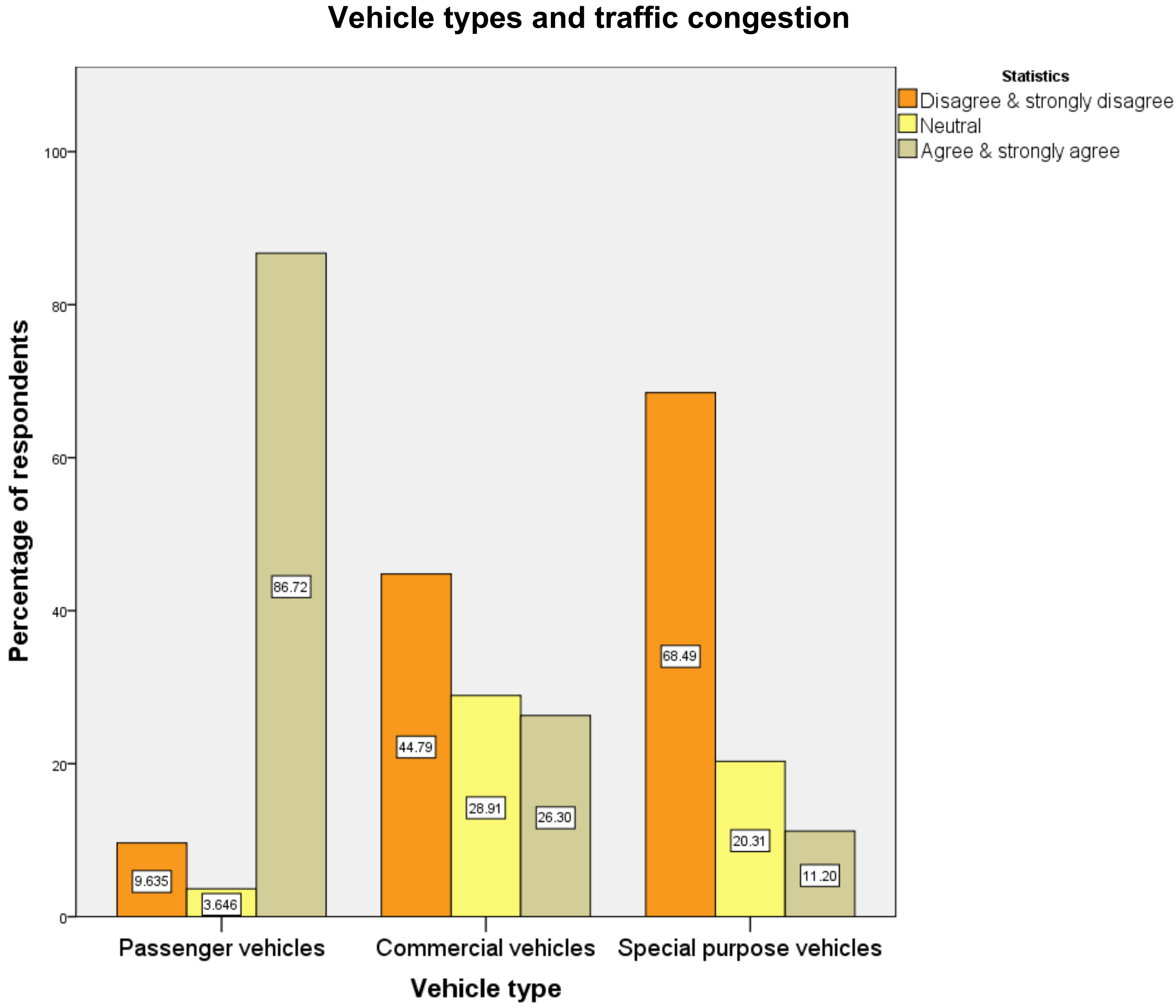


**Figure 4. 9: Vehicle types on traffic congestion**

A total of 384 respondents responded to the contribution of different vehicle types to traffic congestion in EL-CBD, specifically on Oxford Street. As shown in Figure 4.9, a significant majority of participants, comprising 86.72%, indicated agreement or strong agreement regarding the high contribution of passenger vehicles to traffic congestion. Commercial vehicles came next, with 26.30% of respondents acknowledging their substantial contribution, and special-purpose vehicles, with 11.20% admitting their impact on congestion.

### 4.3.2 Exploration of low traffic flow by respondents

Travelling, commuting, or transporting oneself from one location to another is a common activity in everyday life, whether it involves reaching an office, school, mall, clinic, gym, shop, or any other destination. Particularly in the bustling city of EL, this endeavour demands considerable time, energy, and effort from residents and workers alike. However, one of the foremost challenges travellers face is the city's prevalent traffic congestion. This study emphasises exploring commuters' perspectives as a crucial aspect in understanding their sentiments regarding the decline in traffic flow on Oxford Street, recognising the profound impact of this phenomenon on their daily lives.

**Perceptions of traffic congestion severity on EL-Oxford Street:** Respondents' perceptions of traffic congestion were assessed using a 5-point Likert-type scale, ranging from 'major problem' to 'not a problem'. Figure 4.10 presents the distribution of respondents' opinions regarding the severity of traffic congestion on EL's Oxford Street, depicted in percentages.

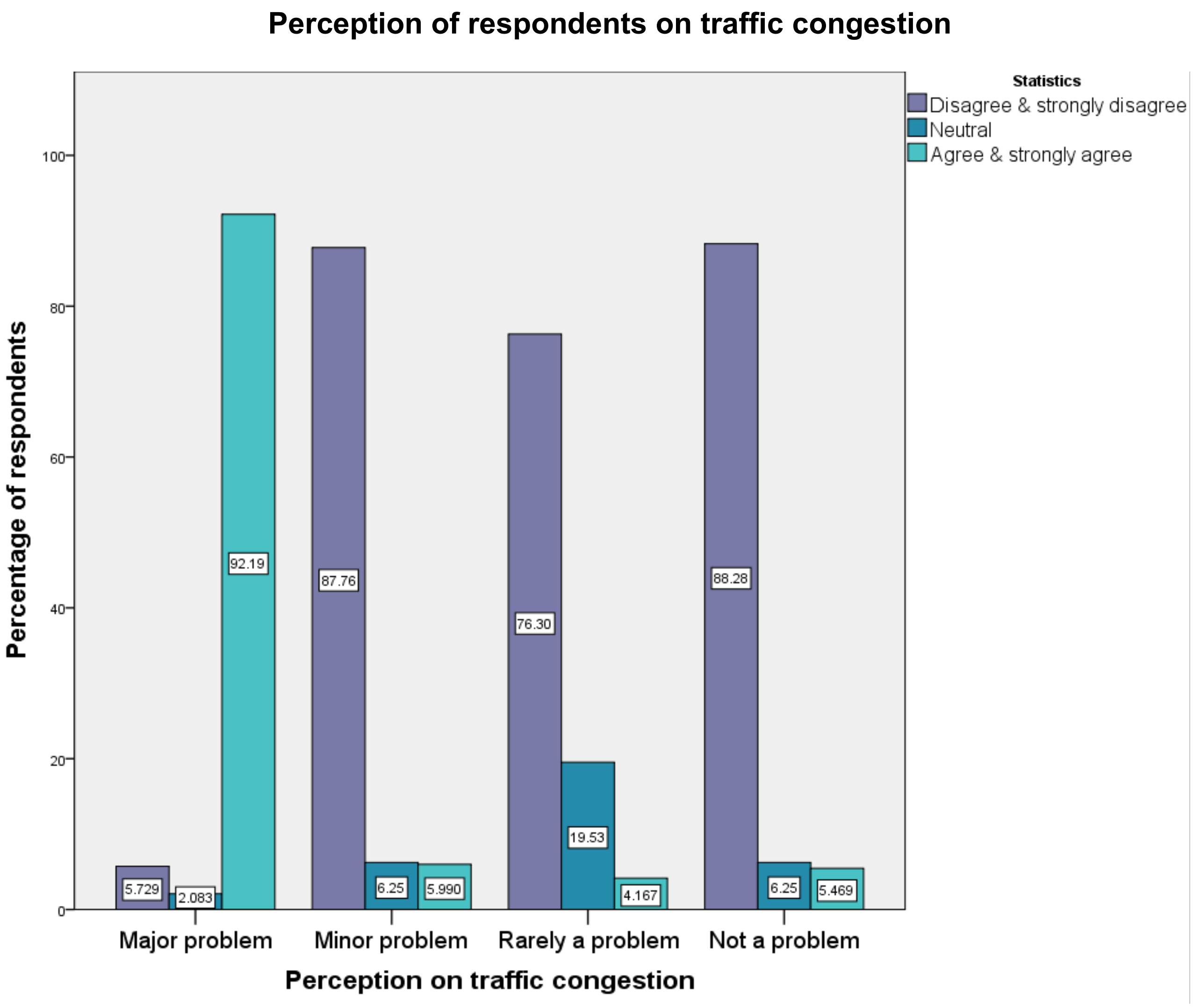


**Figure 4. 10: Illustration of perceptions of traffic congestion severity**

Three hundred eighty-four respondents responded to their perceptions of traffic congestion on Oxford Street. As shown in Figure 4.10, majority of participants, comprising 92.19%, agreed or strongly agreed that traffic congestion is a significant problem. Additionally, 5.99% of respondents agreed or strongly agreed that traffic congestion is a minor problem, while 5.46% believed that traffic congestion is not a problem. Lastly, 4.16% of respondents agreed or strongly agreed that traffic congestion is rarely a problem.

**Perceptions on factors influenced by traffic congestion:** A 5-point Likert-type scale, which is frequently used in surveys to gauge attitudes, perceptions, and opinions, was used to evaluate the respondents' views. Respondents can indicate different levels of agreement or disagreement with a statement using this scale, which usually has a neutral midpoint and ranges from "Strongly Disagree" to "Strongly Agree." The Likert scale was employed in this study to assess respondents' opinions regarding several factors impacted by East London traffic congestion. Air pollution, commute time, stress levels, the impact on the economy, and general quality of life are a few examples of these variables.

Following compilation and analysis of the survey data, the findings are shown in Figure 4.11. This Figure clearly illustrates the distribution of responses by presenting the respondents' opinions as percentages. The Figure makes it simple to compare and understand the relative significance of the various factors causing traffic congestion by displaying the data in percentage form. This method assists in identifying the main problems that East London's residents face due to traffic congestion, which can guide future planning and interventions to address the issue.

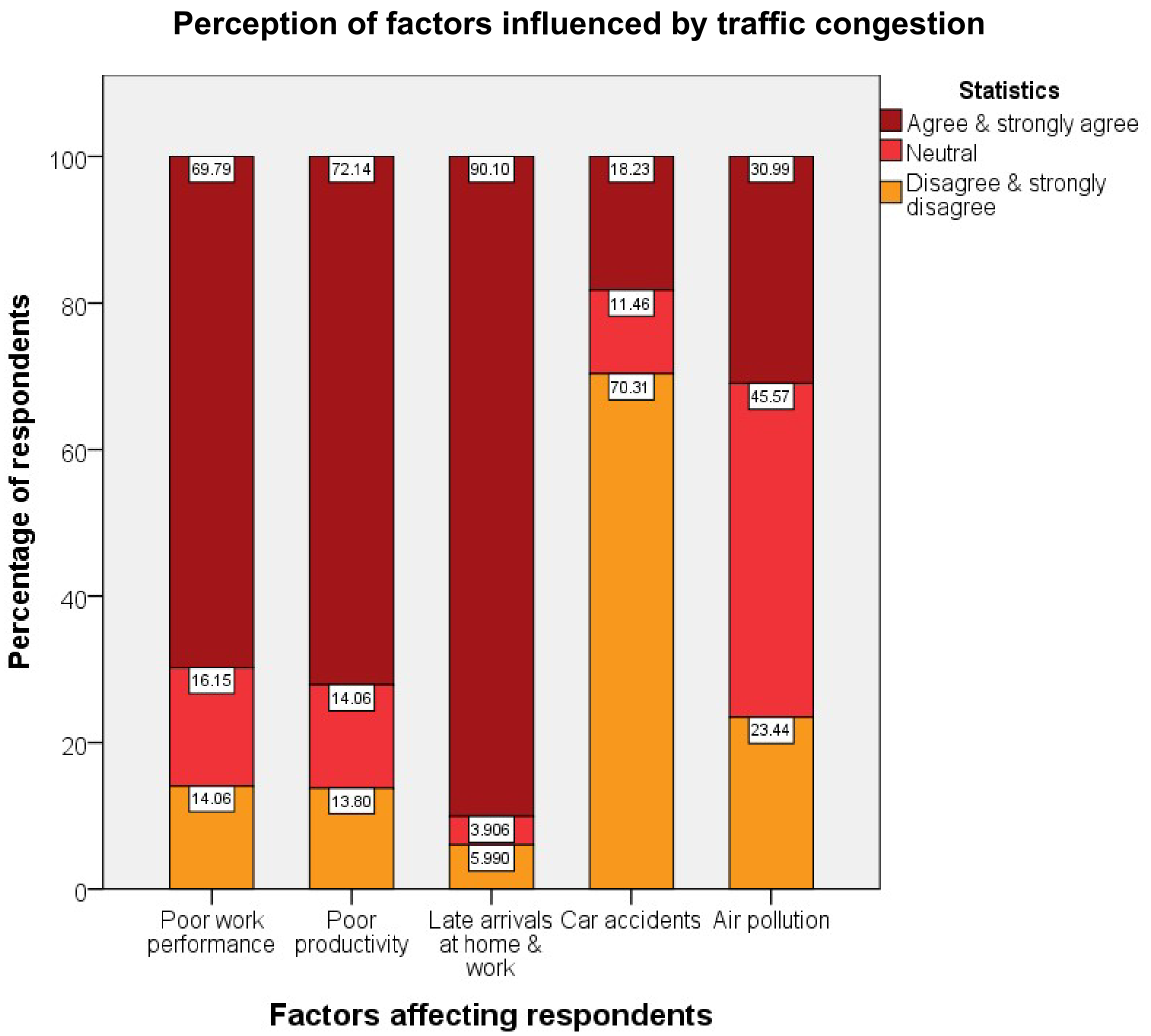


**Figure 4. 11: Perception of factors influenced by traffic congestion**

Three hundred eighty-four respondents responded to their daily experiences on Oxford Street. As shown in Figure 4.11, most participants, comprising 90.10%, agreed or strongly agreed that traffic congestion leads to late arrivals at home and work. Additionally, 72.41% of respondents acknowledged poor work productivity, while 69.79% expressed concerns about poor work performance due to traffic congestion. Furthermore, 30.99% of respondents cited air pollution as a consequence of traffic congestion, followed by car accidents, which 18.23% noted.

According to the data, outside interruptions significantly influence workplace productivity and punctuality. These disruptions are probably caused by inefficient transportation, city traffic, or inadequate infrastructure. Better road networks, more efficient public transportation, and traffic management systems are urgently needed to reduce delays, as evidenced by the overwhelming agreement on late arrivals (90.10%). Although most people do not consider vehicular accidents a serious problem (70.31% disagree), air pollution is still a moderate concern, possibly due to growing urbanisation and industrial activity. According to the responses, improvements in transportation infrastructure, road upkeep, and pollution control measures could increase overall productivity, highlighting a larger concern about how working conditions affect professional efficiency.

**Respondents' satisfaction levels during traffic congestion:** The survey aimed to assess the impact of daily traffic congestion on the experiences and emotions of Oxford Street users. To achieve this, respondents were asked to indicate their satisfaction levels regarding five specific emotional responses: feeling friendly, frustrated, aggressive, tired, and angry. These emotions were measured using a five-point Likert-type scale, ranging from very dissatisfied to very satisfied.

This assessment aimed to understand how traffic congestion influences the mood and overall satisfaction of road users. Figure 4.12 visually represents the survey results, illustrating the distribution of responses across the five emotional categories. This data offers valuable insights into how congestion affects the daily commuting experience and can inform potential strategies to mitigate adverse impacts on road users.

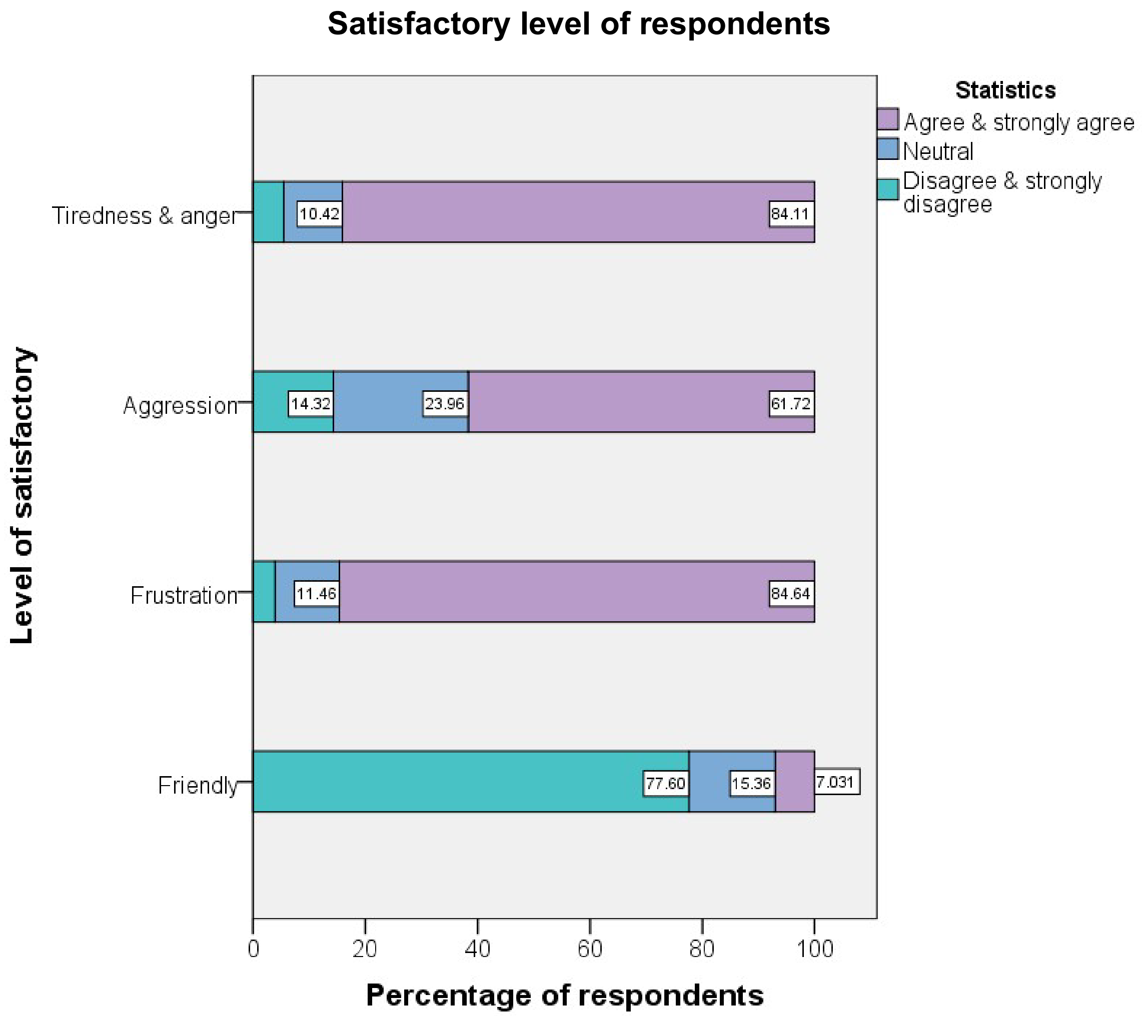


**Figure 4. 12: The level of satisfaction during traffic congestion**

The majority of respondents had emotionally adverse reactions to traffic congestion, according to the data in Figure 4.12. In particular, 84.64% of respondents agreed or strongly agreed that they experience fatigue and rage when there is much traffic. This implies that traffic congestion is a significant source of stress and exhaustion for most people, which may affect productivity and mental health. Chronic stress brought on by ongoing exposure to such circumstances may impact one's general quality of life, health, and productivity at work.

Additionally, 84.11% of respondents said being stuck in traffic irritates them. The perceived inability to control one's surroundings and time, two essential aspects of daily life, may be the source of this annoyance. The high proportion of people who expressed frustration also points to a general discontent with the condition of transportation systems today and a growing consciousness of their shortcomings.

When dealing with traffic congestion, 61.72% of participants felt adversity. In this context, "adversity" probably refers to the idea that traffic is a hindrance to reaching one's objectives, both personal and professional. Since many people believe that traffic congestion negatively impacts their daily routines and long-term goals, this sense of adversity may have wider societal ramifications, especially in urban planning.

On the other hand, only 7.03% of respondents agreed or strongly agreed that it is enjoyable to deal with traffic congestion. This result demonstrates that a small percentage of people find pleasure or benefit in negotiating traffic. These few individuals may be anomalies who are either oblivious to traffic or see it as a chance for introspection, rest, or other advantages.

According to the findings, most people consider traffic congestion a significant cause of stress and unpleasant feelings. Traffic congestion has deeper emotional and psychological effects on day-to-day living than just being an annoyance, as the overwhelming majority of people report experiencing feelings of rage, frustration, and adversity. Furthermore, the almost complete lack of people with a favourable opinion of traffic highlights the need for practical ways to lessen the stress caused by it, such as enhancing public transit, creating better traffic control plans, or investing in congestion-reducing infrastructure.

This data may also indicate the possible societal advantages of lessening traffic congestion. Policymakers and urban planners could alleviate the psychological burden on citizens, increase productivity, and improve public health by tackling these problems. In the end, the study's emphasis on adverse emotional reactions emphasises how critical it is to design commuter environments that are more effective and less stressful.

Beyond merely comprehending public opinion, this analysis and interpretation are significant. It makes a strong case for addressing traffic congestion as an urban planning and public health concern. By addressing the psychological, economic, and social effects of traffic, cities can enhance the quality of life for their citizens, increase productivity, and develop more sustainable, liveable spaces. Policymakers, planners, and innovators can use the findings as a framework and call to action to collaborate on a more effective, stress-free transportation future.

### 4.3.3 Peak period analysis

Peak-period traffic congestion along Oxford Street in East London (EL) represents a significant transportation challenge, primarily due to the existing infrastructure’s inability to accommodate the concentrated spatial and temporal travel demands. This issue requires navigating a complex economic, social, energy, and environmental landscape, especially when considering deploying capital-intensive solutions. This study seeks to assess traffic congestion during peak periods and explore a wide range of strategies to enhance the transportation system's efficiency along Oxford Street in the EL-CBD, focusing on improving mobility and reducing delays.

**Traffic congestion on weekdays:** The frequency of days affected by traffic congestion was assessed using a 5-point Likert-type scale, ranging from 1-2 days per week to 'every day. This scale allowed respondents to express their perceptions of the severity of traffic congestion on Oxford Street over a week. The distribution of respondents' opinions regarding which weekdays are most frequently impacted by traffic congestion is illustrated in Figure 4.13. The Figure presents this data as percentages, offering a clear visual representation of the proportion of respondents who experienced congestion on different days of the week. By analysing this data, we can gain valuable insights into peak congestion periods and better understand the traffic flow patterns on Oxford Street.

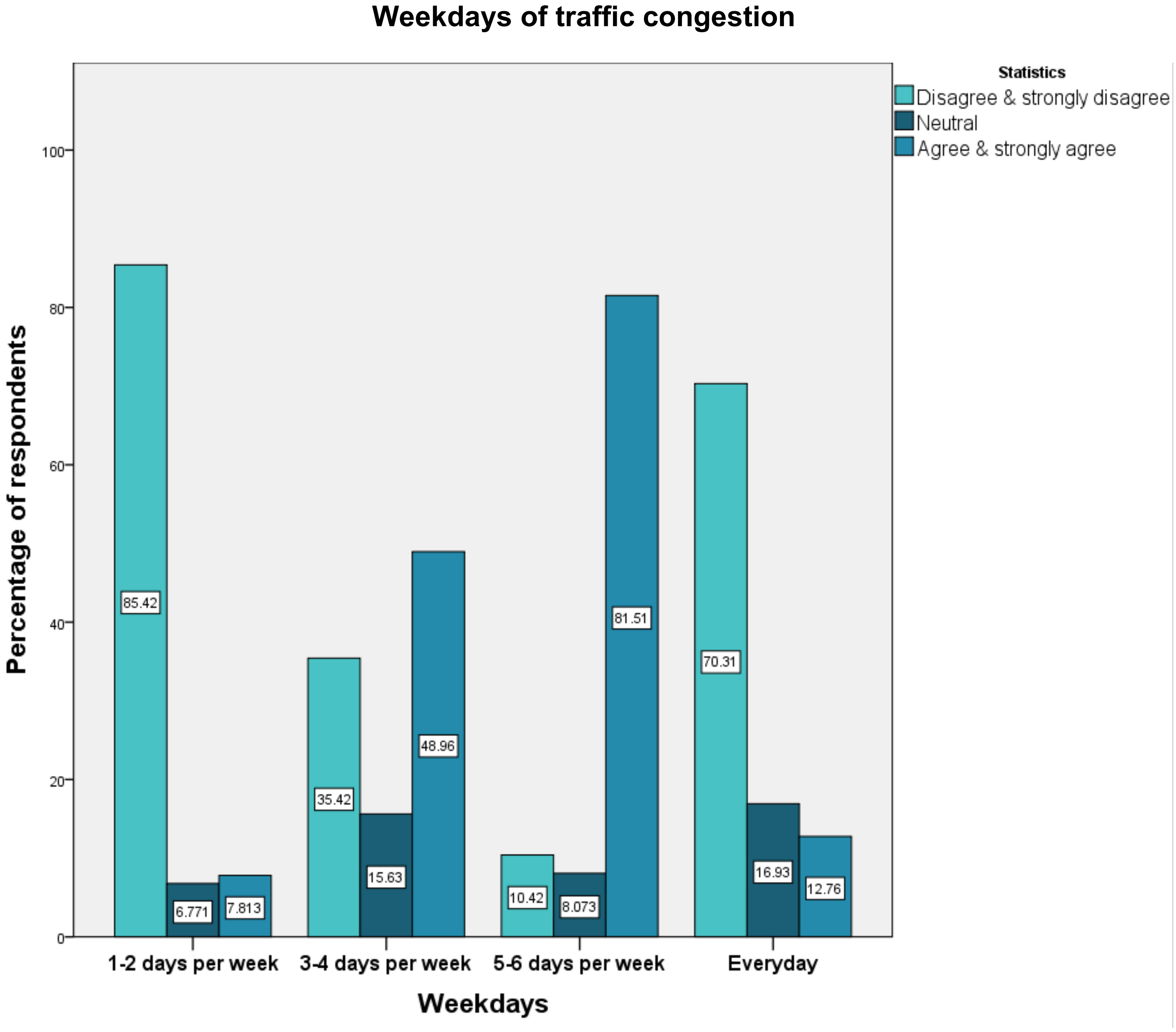


**Figure 4. 13: Illustration of the weekdays of traffic congestion**

A total of 384 respondents responded to the frequency of traffic congestion on Oxford Street. As shown in Figure 4.13, most respondents, accounting for 81.51%, indicated that traffic congestion occurs 5-6 days per week. Additionally, 48.96% of respondents reported experiencing congestion on 3-4 days per week, while 12.76% noted congestion every day. Finally, 7.81% of respondents reported traffic congestion on 1-2 days per week. The high percentage of congestion occurring on Oxford Street 5-6 days per week could be attributed to the typical workweek schedule, where individuals commute to work from Monday to Friday, and some may even work on Saturdays, leaving Sundays for relaxation at home.

Three hundred eighty-four respondents provided feedback regarding the frequency of traffic congestion on Oxford Street. As illustrated in Figure 4.13, most respondents (81.51%) reported experiencing traffic congestion on this roadway five to six days per week. This suggests congestion is a persistent issue most weekdays, likely influenced by daily commuting patterns. Additionally, 48.96% of respondents indicated that they encounter traffic congestion three to four days per week, while 12.76% stated that congestion occurs every day, highlighting the severity of the problem. A smaller portion of respondents (7.81%) noted that congestion is limited to only one or two days per week.

The high frequency of congestion, particularly the 5-6 days per week category, can be attributed to the typical workweek schedule, where most individuals commute between Monday and Friday, with some extending their work activities into Saturdays. The increased vehicular movement during peak hours, such as morning and evening rush hours, likely exacerbates congestion levels. Furthermore, commercial activities, public transportation routes, and infrastructure limitations may contribute to the recurring traffic bottlenecks observed on Oxford Street. On the other hand, Sundays tend to experience lower traffic volumes as many people stay home or engage in leisure activities, temporarily alleviating congestion.

Understanding these traffic patterns is essential for developing effective traffic management strategies, such as optimising signal timing, implementing road expansions, or promoting alternative transportation options to reduce congestion and improve mobility along Oxford Street.

The analysis and interpretation of traffic congestion frequency on Oxford Street are significant for several reasons. By identifying that most respondents' experience congestion 5-6 days per week, planners and policymakers can recognise the urgency of addressing traffic issues. This data helps design strategic interventions such as optimising traffic signals, introducing dedicated lanes, or modifying road infrastructure to improve traffic flow.

Understanding congestion trends allows authorities to assess whether the current road infrastructure meets demand. Persistent congestion may indicate the need for road expansions, additional bypasses, or improved public transport systems.

Policymakers can use this data to justify investments in road networks or alternative transport solutions such as cycling lanes or pedestrian-friendly zones. The insights gained from this study can guide transportation planning efforts, such as adjusting public transport schedules to accommodate peak congestion hours or introducing carpooling incentives. A better understanding of daily traffic patterns also aids in developing long-term strategies for sustainable urban mobility.

**Peak hours of traffic congestion:** Section B of the questionnaire included a key question to assess respondents' perceptions of traffic congestion along Oxford Street in East London. Specifically, participants were asked to identify the typical peak periods during which congestion is most prevalent. The provided response options included five distinct time ranges: 6:00 AM – 10:00 AM, 10:00 AM – 2:00 PM, 2:00 PM – 6:00 PM, 6:00 PM – 10:00 PM, and 10:00 PM onwards.

Figure 4.14 presents a graphical representation of the collected responses, illustrating the distribution of perceived peak congestion periods as percentages. This data offers valuable insights into traffic flow patterns, which may assist in developing targeted traffic management strategies and infrastructure improvements to alleviate congestion on Oxford Street.

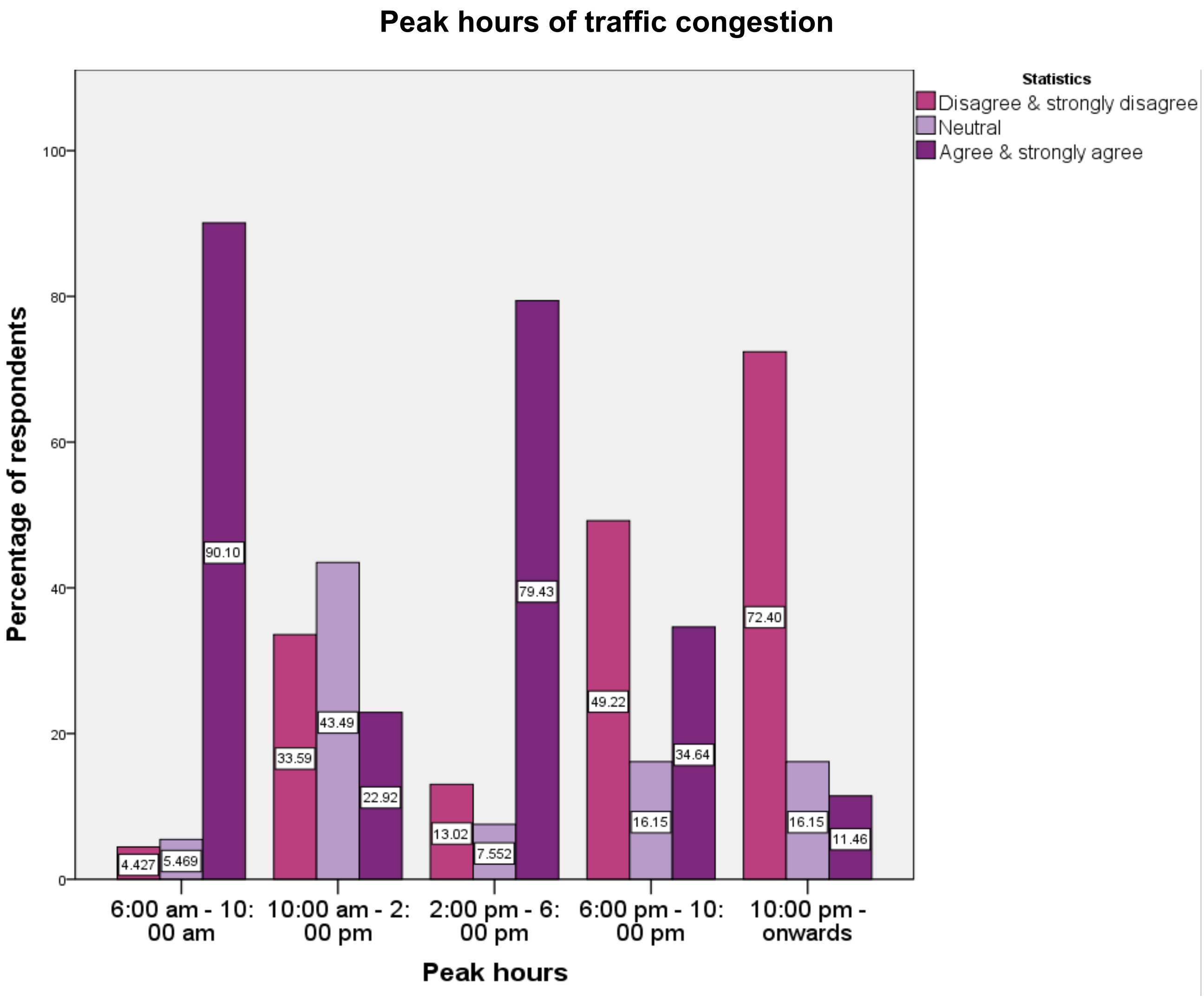


**Figure 4. 14: Illustration of traffic congestion peak hours**

The findings on peak traffic congestion on Oxford Street in East London (EL) provide significant insights for urban transportation planning, traffic management, and policymaking. The responses indicate that congestion predominantly occurs during two peak periods: 6:00 am – 10:00 am (90.10%) and 2:00 pm – 6:00 pm (79.83%), aligning with global rush-hour traffic trends associated with work and school commutes. These results reinforce key themes from the literature review and highlight the pressing need for strategic interventions to alleviate congestion.

The results confirm that peak congestion on Oxford Street follows typical urban congestion trends, where traffic volume surges in the morning and late afternoon due to work and school commutes. This aligns with Zhao & Hu (2019) and Mkulisi

& Sinclair (2021), who found that peak congestion hours in most urban centres occur during these timeframes due to daily commuter movement. These findings suggest that traffic congestion in EL is primarily demand-driven, influenced by the limited availability of efficient public transportation and a reliance on private vehicles.

The fact that congestion peaks during these periods reinforces the literature's argument that urban traffic congestion is exacerbated by increased private vehicle ownership and insufficient public transport options (Saeidizand et al., 2022; Marshall & Dumbaugh, 2020). Studies by Cele (2018) and Suman & Bolia (2019) highlight that cities with limited public transit infrastructure experience severe congestion during peak hours as individuals resort to private vehicle use, further burdening road networks. The results from Oxford Street suggest that many commuters rely on private transport, indicating the need for public transit enhancements.

The precise identification of congestion peak periods presents an opportunity for targeted interventions. As the literature emphasises, congestion can be alleviated through optimised traffic signal timing, carpooling initiatives, dedicated bus lanes, and congestion pricing during peak hours (Mounce & Nelson, 2019; Mulley & Kronsell, 2018).

### 4.3.4 Uncertainties influencing transportation system performances

Uncertainty in transportation systems is commonly associated with adverse effects, including escalated operational costs, diminished resource efficiency, and decreased customer satisfaction. The following subsections elucidate the ramifications of uncertainty on transportation system performance, leading to a reduction in traffic flow along Oxford Street, EL.

**The behavioural factors of drivers contributing to congestion:** According to Song et al. (2021), driver behaviour encompasses intentional and unintentional actions exhibited by individuals while operating a motor vehicle. These behaviours can be influenced by a wide range of factors, including demographic characteristics such as age, gender, and driving experience, as well as psychological and environmental elements such as attitude, emotions, fatigue, drowsiness, and prevailing traffic or road conditions. Understanding driver behaviour is crucial in assessing its impact on road safety, traffic efficiency, and congestion levels.

In this study, respondents' perceptions regarding driver behaviour were assessed using a five-point Likert-type scale, allowing participants to express their agreement or disagreement with various statements related to driving habits and their contribution to traffic congestion. The data collected provides insight into how different driving tendencies, such as reckless driving, sudden lane changes, failure to yield, and excessive speeding, may exacerbate congestion issues.

Figure 4.15 presents the distribution of respondents' opinions on the role of driver behaviour in contributing to traffic congestion, expressed as percentages. This visual representation highlights the varying degrees of consensus among participants, shedding light on the extent to which driver-related factors are perceived to influence traffic flow and road network efficiency. The findings from this analysis may help inform strategies to improve driver awareness, enforce traffic regulations, and mitigate congestion through targeted interventions.


**Figure 4. 15: Behaviour of drivers**

The results on driver behaviour and its contribution to traffic congestion, as presented in Figure 4.15, reveal significant insights into how driver actions influence road conditions and congestion. Most respondents indicated that non-compliance with traffic signs, disregarding traffic signals, and failing to follow road regulations were prevalent behaviours, which can exacerbate congestion and impede the smooth flow of traffic. These findings are consistent with existing literature on the relationship between driver behaviour and traffic congestion, offering important implications for traffic management and urban planning. Below is a discussion of the significance of the results, tied to the literature review.

77.86% of respondents agreed that drivers often fail to comply with traffic signs, indicating that a significant portion of the congestion issue may stem from behavioural factors. Disregarding traffic signs can lead to confusion, disorganisation, and unsafe driving practices, all contributing to congestion. According to Song et al. (2021), non-compliance with traffic signs and signals can lead to accidents, delays, and more complex traffic patterns, ultimately exacerbating congestion. This is because such behaviour can cause sudden stops, lane changes, or detours, disrupting the traffic flow and leading to bottlenecks. The results emphasise the need to enforce traffic regulations and public education campaigns to encourage compliance.

The high percentage of respondents (76.30%) reporting that drivers ignore traffic signals further reinforces the notion that driver behaviour plays a significant role in congestion. When drivers disregard traffic signals, it can cause conflicting movements, block intersections, and prevent the smooth traffic flow. Song et al. (2021) highlight that this behaviour can lead to significant disruptions, such as traffic gridlocks, particularly at busy intersections, where traffic signal coordination is crucial for maintaining an orderly flow. The results suggest a need for stricter law enforcement and potentially more innovative traffic systems that can adapt to real-time traffic conditions, minimising the impact of such behaviour on congestion.

Similarly, 73.70% of respondents noted that drivers fail to stop at stop signs, which can lead to additional delays and disrupt the progression of vehicles along a route. According to the literature, such non-compliant behaviour may result in unsafe driving situations, leading to accidents or near misses that cause traffic delays and lower road safety. This behaviour also reflects a general disregard for road rules, which may contribute to the overall inefficiency of the traffic system. The findings highlight the importance of improving road user education and enforcing stop sign compliance to prevent these delays.

A substantial number of respondents (71.09%) also observed that drivers often fail to yield to pedestrians, another significant contributor to traffic congestion. This behaviour disrupts pedestrian and vehicle interactions, forcing pedestrians to wait longer at crossings, thereby slowing down traffic. The literature by Song et al. (2021) discusses how pedestrian-vehicle conflicts are common in urban areas with high foot traffic. Poor driver behaviour in yielding to pedestrians contributes to increased delays and can lead to situations where pedestrians become more aggressive in crossing the road, further exacerbating congestion. Addressing this issue requires stricter enforcement of pedestrian laws and public education on the importance of pedestrian safety.

The responses also indicate that a smaller portion of respondents (28.13%) observed drivers driving too fast, while 24.22% reported that some drivers were moving too slowly. While these behaviours are not as prevalent as non-compliance with signs, they still contribute to traffic inefficiencies. Speeding can cause sudden braking, accidents, or lane changes, while driving too slowly can cause frustration, tailgating, and create congestion in specific lanes. As the literature points out, high and excessively slow speeds can disturb the traffic flow, increase the likelihood of accidents, and contribute to bottlenecks (Song et al., 2021). This suggests a need for better regulation of speed limits and enhanced awareness about the impact of varying driving speeds on traffic congestion.

The findings regarding driver behaviour align closely with the literature on traffic congestion. According to Song et al. (2021), the role of driver behaviour in traffic congestion cannot be overstated, as it is directly linked to road safety, traffic flow, and overall efficiency. The results from this study demonstrate that non-compliance with traffic signs and signals, failure to yield to pedestrians, and erratic driving behaviour are some of the most prominent behaviours contributing to congestion. These behaviours lead to inefficiencies in traffic movement and create difficult situations, especially in urban settings.

The literature review highlights that poor driver behaviour is one of the major contributors to traffic congestion, particularly in busy urban areas (Rodrigue, 2020). Inconsistent driving practices, such as ignoring traffic regulations, not stopping at stop signs, and speeding, are known to create bottlenecks, accidents, and delays, which, in turn, exacerbate congestion. Song et al. (2021) argue that improving driver behaviour is critical to mitigating traffic congestion and enhancing the overall efficiency of the road network.

Furthermore, the findings align with research by Mulley & Kronsell (2018), which emphasises that addressing driver behaviour through both enforcement and education can significantly impact traffic congestion. Public awareness campaigns and stricter traffic law enforcement are necessary to curb non-compliant driving behaviours, thereby improving traffic flow and reducing congestion.

**Key factors contributing to traffic congestion on Oxford Street:** The problem-related inquiries in this study were designed to identify the underlying factors contributing to the persistent traffic congestion experienced by users of Oxford Street. These questions, aligned with the study’s primary objective (refer to Appendix B: Questionnaire, Section B, Question 15), explore a wide range of issues, guided by existing literature on traffic management and urban transportation. The factors investigated include limited parking space, high traffic volumes, inadequate road infrastructure, reckless driving, car accidents, numerous pedestrian crossings, ongoing road construction and maintenance projects, illegal passenger loading and unloading, insufficient lane widths, and improper signal design.

Furthermore, the study also examines non-compliance with traffic regulations, and the presence of taxi ranks within the East London Central Business District (EL-CBD). Each of these factors, individually or collectively, plays a significant role in the traffic delays and congestion experienced daily.

Figures 4.16, 4.17, and 4.18 detail the study’s findings, categorising the contributing factors into three broad groups, which are then analysed as a unified whole. These Figures illustrate the responses gathered from the questionnaire, reflecting the extent to which respondents agree, disagree, or remain neutral on each factor's impact on traffic congestion. By analysing these responses, the study aims to highlight the key elements that exacerbate traffic flow disruptions, offering valuable insights into how these issues might be addressed. The data captured in these Figures provides a comprehensive overview of public perceptions regarding the various contributors to congestion, thereby offering a clearer picture of which factors require immediate attention and improvement to alleviate daily traffic issues.

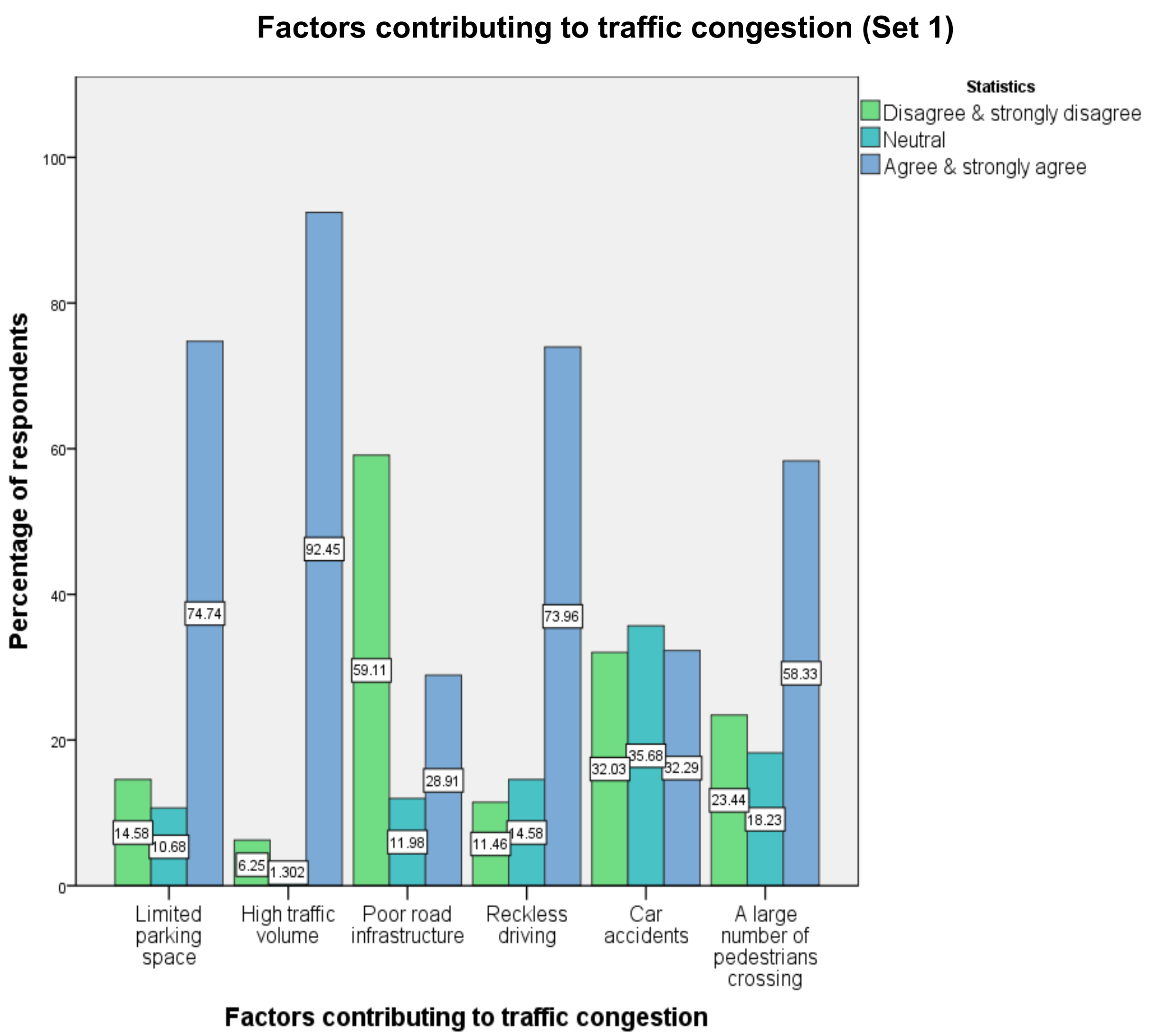


**Figure 4. 16: Factors contributing to traffic congestion (Set 1)**

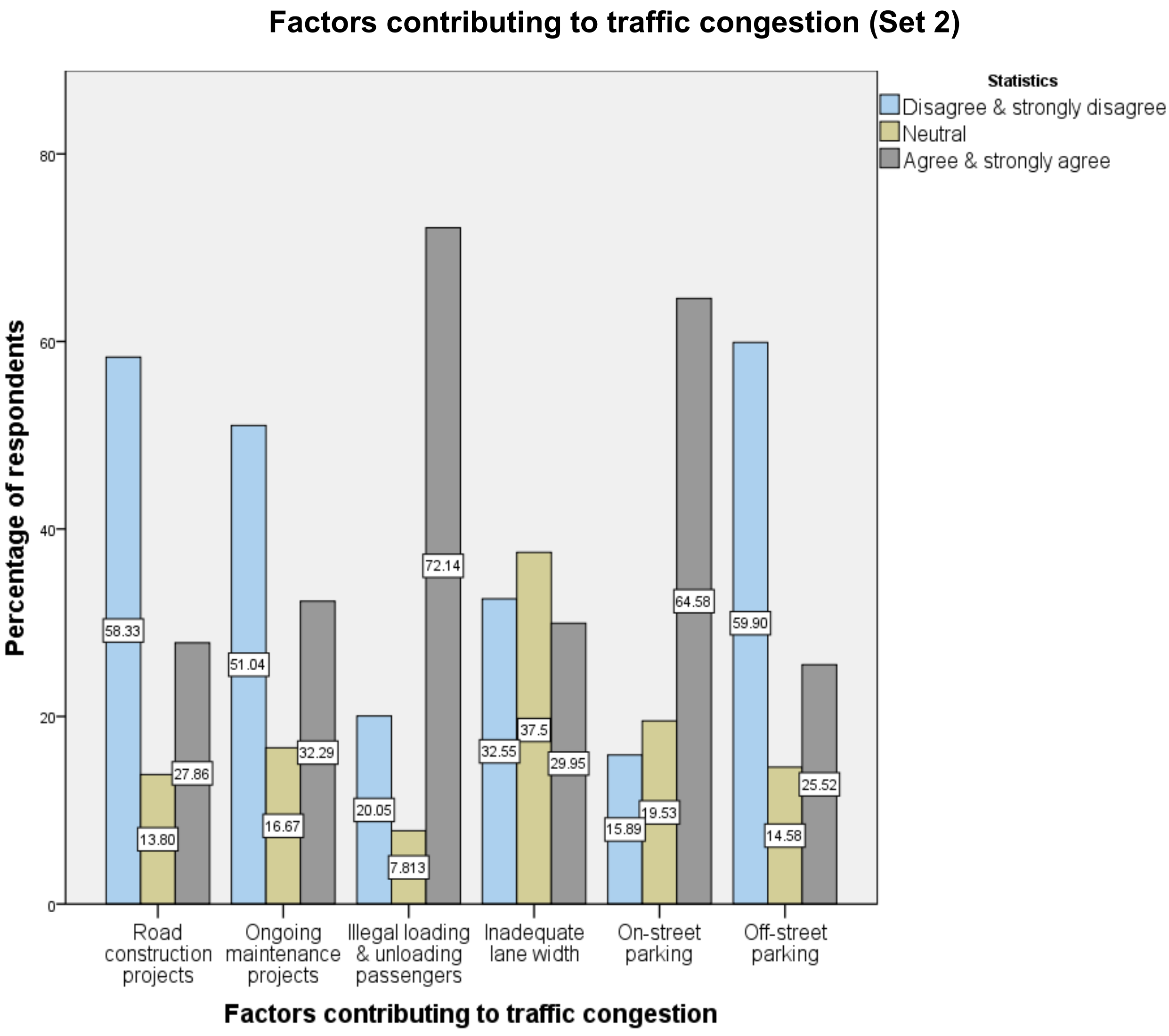


**Figure 4. 17: Factors contributing to traffic congestion (Set 2)**

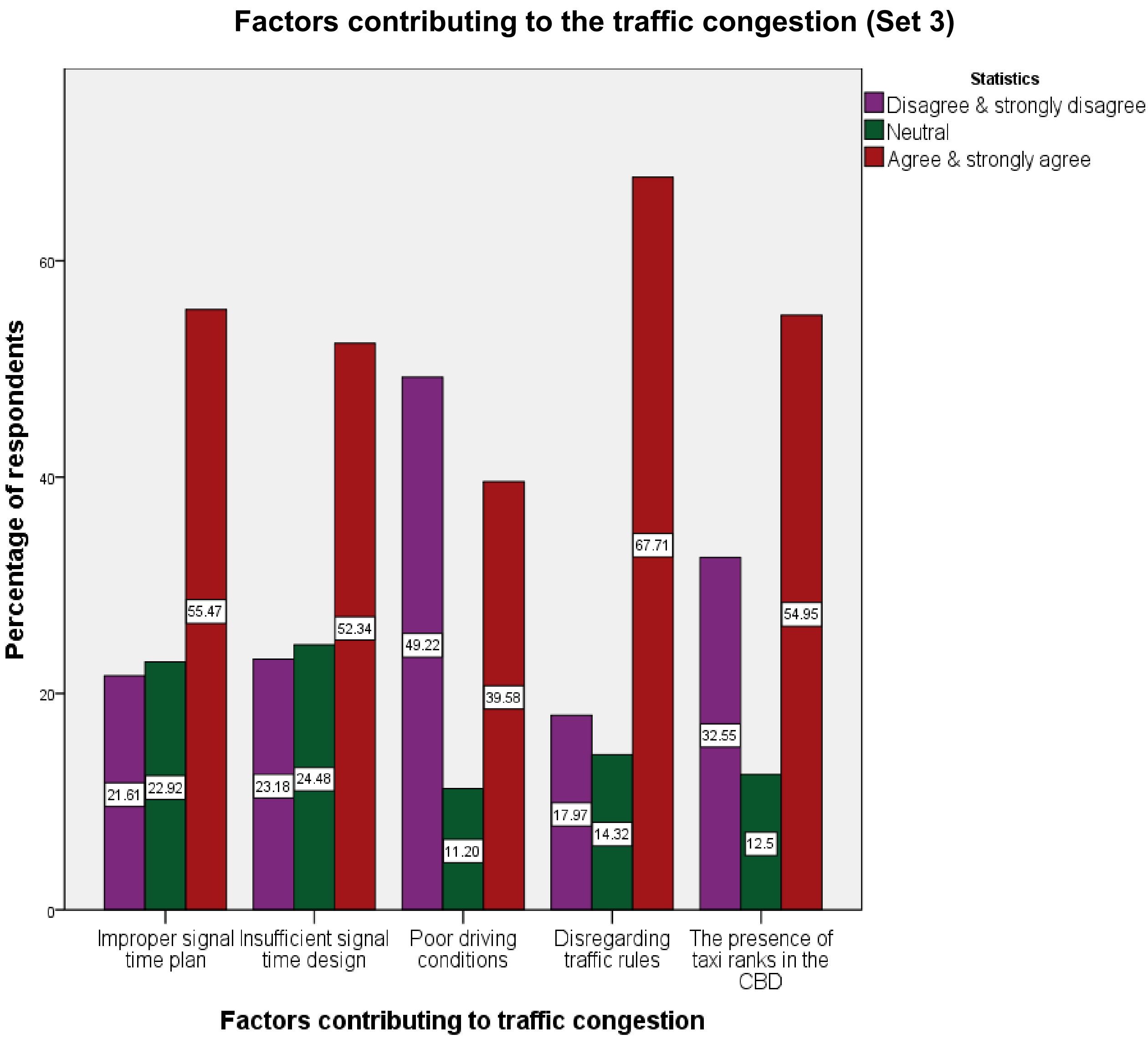


**Figure 4. 18: Factors contributing to traffic congestion (Set 3)**

The results regarding the factors contributing to traffic congestion on Oxford Street, as presented in Figures 4.16, 4.17, and 4.18, highlight significant issues that exacerbate congestion in urban areas like East London (EL). These findings hold important implications for urban planning, traffic management, and infrastructure development and are aligned with existing literature on traffic congestion and urban transportation challenges. Below is a discussion of the significance of these results, tying them back to the literature review.

The overwhelming consensus that high traffic volume is the primary cause of congestion (92.45%) reflects the well-documented trend in urban centres worldwide. As noted in the literature (Rose, 2018; Zhao & Hu, 2019), the growing number of private vehicles, driven by increased car ownership, is a key contributor to congestion. The high agreement rate among respondents further emphasises that traffic volume, particularly during peak hours, is the dominant factor exacerbating congestion on Oxford Street. This insight suggests the need for improved traffic management strategies, including better public transportation options, carpooling initiatives, and policies to reduce the reliance on private vehicles, as discussed in the literature.

Limited parking space, identified by 74.74% of respondents, contributes significantly to congestion. The literature review highlighted that urban areas, particularly those with high vehicle ownership, struggle with insufficient parking (Hoehne et al., 2019; Mingardo et al., 2015). This lack of parking leads to vehicles circling the area, searching for spots, further clogging the roads and disrupting traffic flow. As discussed in the literature, parking policies such as implementing parking restrictions or developing off-street parking spaces could help alleviate this issue and improve the overall traffic situation.

Reckless driving and non-compliance with traffic regulations were major contributors to congestion. The high agreement rate (73.96% for careless driving and 67.71% for non-compliance) aligns with findings in the literature (Mounce & Nelson, 2019; Marshall & Dumbaugh, 2020), where human behaviour is seen as a critical factor in traffic congestion. Reckless driving, such as speeding, overtaking in inappropriate areas, and failure to yield, disrupts the smooth traffic flow, leading to delays and increased congestion. Additionally, non-compliance with traffic rules often results in accidents or near-miss situations, further compounding the congestion problem.

The impact of illegal passenger loading and unloading (72.14%) is particularly relevant in urban environments with high taxi and minibus activity, such as EL. This issue is frequently cited in the literature as a key factor in urban traffic congestion (Saeidizand et al., 2022). Taxis often stop in non-designated areas to pick up or drop off passengers, causing blockages in traffic flow, especially during peak hours.

The study's findings indicate the need for dedicated passenger pick-up and drop-off zones and better regulation of taxi operations to reduce congestion.

Poor Road infrastructure, identified by 59.11% of respondents, contributes to traffic congestion by limiting the capacity and efficiency of the road network. The literature review also emphasised that inadequate infrastructure, such as poorly maintained roads, limited lanes, and outdated traffic management systems, significantly hampers the smooth flow of traffic (Rodrigue, 2020). In the context of Oxford Street, road infrastructure improvements, including road widening, better traffic management, and the introduction of intelligent traffic systems, could help alleviate congestion.

Numerous pedestrian crossings (58.33%) were also identified as a contributing factor. In high-footfall urban areas, pedestrian crossings can cause significant delays as vehicles stop to allow pedestrians to cross. The literature review discussed how pedestrian traffic management is critical to balancing the flow of pedestrians and cars, with solutions such as pedestrian bridges or underpasses to reduce interruptions to vehicle flow (Thombre & Agarwal, 2021).

Factors such as inadequate lane width (37.5%), ongoing road construction (51.04% disagreement), and off-street parking (59.9% disagreement) received lower levels of agreement, indicating that respondents do not see them as primary contributors to congestion. This suggests that while these issues may still have some impact, they are not as critical as traffic volume, parking space limitations, and reckless driving. The literature review similarly notes that congestion caused by construction projects and lane width limitations is often temporary and may not have the same long-term impact as factors like traffic volume and parking (Suman & Bolia, 2019).

### 4.3.5 Traffic congestion measures

Addressing congestion requires a multifaceted approach, as no single solution can adequately resolve the complexity of traffic challenges in major metropolitan areas. Each strategy plays a vital role in mitigating congestion to varying degrees, yet none alone can comprehensively alleviate the extent of the problem.

Effective traffic management, such as prompt clearance of accidents and stalled vehicles and optimised signal coordination, enhances operational efficiency on roadways. Providing alternative travel options offers affordable alternatives to driving, thereby alleviating strain on existing infrastructure. System modification tactics, employing innovative techniques, optimise the utilisation of available road space.

Below, the study outlines examples of the implementation strategies, as suggested by participants. These examples constitute a diverse and evolving array of approaches to address congestion, categorised for clarity and comprehensiveness.

**Public perception on alleviating congestion:** This section presents a comprehensive overview of various measures to reduce traffic congestion, aligning with the study's objectives outlined in Appendix B (Questionnaire, Section B, Question 16). Participants were tasked with identifying the most effective strategies to alleviate congestion, specifically on Oxford Street in East London (EL).

To facilitate the assessment, the measures were grouped into eight key categories: improved public transportation systems, optimised traffic signal timings, carpooling initiatives, enhancement of road infrastructure, implementation of efficient parking management strategies, promotion of flexible work hours and telecommuting options, the introduction of local bus services, and the provision of real-time traveller information. These strategies were evaluated based on their potential to ease traffic flow and improve overall commuting experiences for residents and visitors. The outcomes, which highlight the best practices identified by participants, are visually represented in Figure 4.19, providing insight into the most effective approaches for mitigating traffic congestion on Oxford Street.

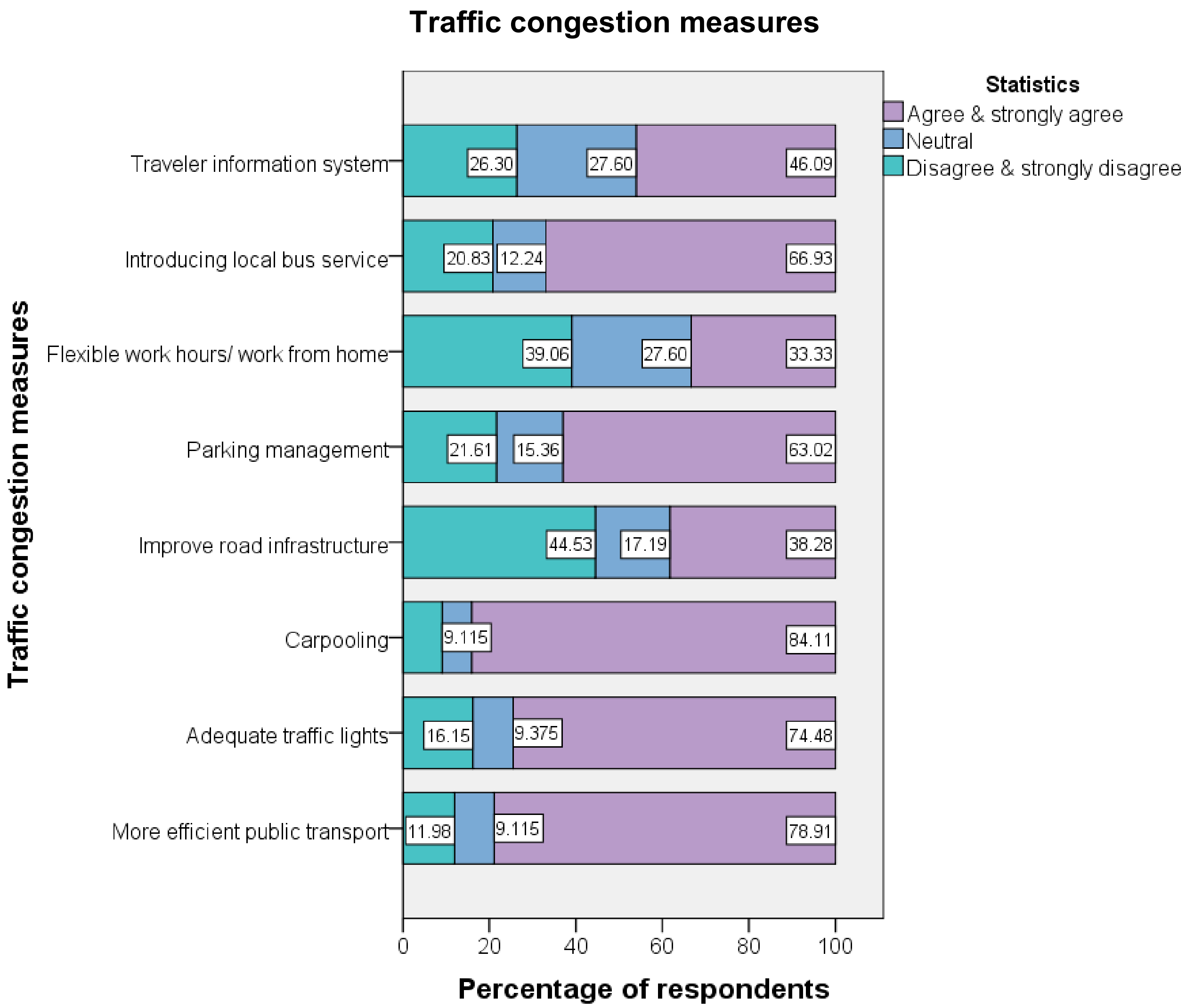


**Figure 4. 19: Public perception on alleviating congestion**

The results regarding public perception on measures to alleviate traffic congestion on Oxford Street (Figure 4.19) offer valuable insights into the strategies that the respondents most favour. These findings significantly affect transportation planning, urban mobility, and traffic management in East London (EL). Below is a discussion of the significance of the results, linking them back to the literature review.

The high level of support for carpooling initiatives (84.11%) underscores the growing recognition of carpooling as an effective solution to reduce traffic congestion. As noted in the literature, carpooling has become increasingly popular as an environmentally friendly alternative to private vehicle use (Ferrero et al., 2018). By consolidating multiple commuters into fewer vehicles, carpooling can significantly reduce the number of cars on the road, easing congestion, reducing air pollution, and enhancing road efficiency. This finding aligns with the literature, emphasising that carpooling programs are cost-effective and environmentally sustainable solutions for urban congestion (Oeschger et al., 2020). The widespread public endorsement of carpooling also suggests that people are more willing to adopt alternative transportation methods if they are well-organised and incentivised.

A majority of respondents (78.91%) expressed support for improving the efficiency of public transportation as a means to alleviate congestion. The importance of public transportation in addressing urban congestion is well-documented in the literature (Leonard et al., 2020; Luke & Heyns, 2020).

As urban populations grow, efficient public transport systems are vital in reducing the reliance on private vehicles. The results suggest a public appetite for better public transportation options that are reliable, frequent, and affordable. This finding is consistent with studies that emphasise the role of public transportation in reducing congestion and improving overall urban mobility (Mamabolo & Sebola, 2018). The push for enhanced public transit also aligns with global trends, where cities increasingly prioritise developing comprehensive, integrated transport systems to reduce traffic congestion and pollution.

A significant portion of respondents (83.90%) agreed with the need for optimised traffic signal timing to regulate traffic flow. The literature highlights the critical role of traffic management systems, such as synchronised traffic signals, in improving traffic flow and reducing congestion (Rodrigue, 2020). Properly timed signals can minimise delays, prevent bottlenecks, and ensure smoother traffic movement, particularly in urban areas where congestion is common. This finding indicates that respondents recognise the value of efficient traffic control measures and are likely to support the implementation of technologies such as intelligent traffic systems that adapt to real-time traffic conditions. The literature also points to the growing use of intelligent transportation systems (ITS) to optimise traffic flow in major metropolitan areas (Mulley & Kronsell, 2018).

The introduction of local bus services garnered 66.93% support. Public bus services are essential to the transportation network, especially in areas with high population density or traffic congestion. The literature (Luke & Heyns, 2020) suggests that local bus services can play a pivotal role in reducing congestion by offering a viable alternative to private car use. However, for bus services to be effective, they must be reliable, affordable, and well-integrated with other forms of public transport. The moderate support for local buses indicates that respondents may see them as a beneficial, but perhaps secondary, solution to congestion, depending on other factors such as frequency and convenience.

Parking management strategies received 63.02% support. The literature indicates that proper parking management, such as introducing parking restrictions or pricing, can reduce congestion by discouraging unnecessary car use (Mingardo et al., 2015). With limited parking spaces in urban areas, efficient parking management can also prevent vehicles from circling the area and looking for a parking space, exacerbating congestion. The finding that parking management is a valuable solution suggests that respondents know the challenges parking poses to smooth traffic flow and are open to measures to address this issue.

The lower levels of support for traveller information systems (46.09%) and road infrastructure improvements (38.28%) suggest that while these measures are essential, they are not seen as the most urgent or impactful solutions to the congestion problem. The literature review notes that while traveller information systems can provide real-time data to commuters and help them make informed decisions, they are generally more effective in conjunction with other measures (Thombre & Agarwal, 2021). Similarly, road infrastructure improvements are often seen as a long-term solution. They may not immediately impact congestion if other, more pressing issues, such as traffic volume and public transport efficiency, are not addressed first (Rodrigue, 2020).

Flexible work hours and telecommuting options received the lowest level of support (58.90%). While the literature suggests that policies promoting flexible work hours or remote work can help reduce peak-hour congestion (Zhao & Hu, 2019), the moderate support for this option may reflect the challenges of widespread adoption, particularly in industries where remote work is not feasible. Additionally, while flexible work hours can help spread traffic, they may not have the same immediate impact as improving public transportation or carpooling.

### 4.3.6 Scientific and technical insights of the study

The data support the idea that a city's economic growth frequently surpasses the advancement of its transportation system. The traffic problems in EL are not particular; instead, they are a sign of larger urbanisation issues that many developing cities worldwide are dealing with. According to the survey, traffic has a detrimental economic impact on East London and affects people's time. This is consistent with other financial and transportation studies highlighting how crucial it is to reduce traffic to increase urban efficiency.

From a scientific perspective, a significant contributing factor to the worsening of traffic is the interaction between behavioural characteristics (such as careless driving and disregard for traffic laws) and insufficient infrastructure (such as restricted public transportation and parking problems). Addressing driver behaviour and infrastructure deficiencies through urban planning, enforcement, and education is crucial.

Studies highlighting the psychological and social elements contributing to traffic congestion align with the substantial role that careless driving and noncompliance with traffic laws play. One of the more challenging aspects of congestion management is driver behaviour, which includes impatience and disobedience to traffic laws. However, as the survey suggests, improving traffic flow and safety may result from tackling this problem with education, behavioural interventions, and more stringent enforcement.

The results highlight the necessity of a multifaceted strategy to alleviate urban congestion, emphasising the incorporation of sustainable urban mobility plans that prioritise the expansion of public transportation, the enhancement of road infrastructure, and campaigns to modify behaviour. Improving road infrastructure, enforcing traffic laws, encouraging eco-friendly alternatives like carpooling, and increasing the effectiveness of public transportation should be the main goals of policy.

Congestion can also be lessened by implementing systems like effective bus networks and intelligent traffic management, as well as by changing laws like road pricing and carpooling incentives. According to peak period analysis, specific actions, like improved signal timing and bus and carpool-only lanes, can reduce traffic during rush hours, resulting in more efficient traffic flow and fewer vehicles on the road.

## 4.4 Traffic Volume Analysis

Focusing on Oxford Street, this report analyses the classified traffic volume data gathered from essential intersections in the East London CBD. The study includes North End Street, Caxton Street, and Union Street intersections. Traffic counts were conducted for 16 consecutive hours (6:00 to 22:00) during the data collection from 16th to 30th July 2023.

This analysis aims to evaluate the traffic flow patterns at these busy intersections, essential to East London's transport system. This study sheds light on traffic dynamics and identifies possible areas for infrastructure and traffic management improvement by looking at various vehicle types, including passenger cars, minibuses, taxis, heavy buses, trucks, and motorcycles.

While the traffic count survey recorded the directions of vehicle movements, this data was not utilised in the subsequent traffic analysis. The primary focus of the study was on overall traffic volume and vehicle classification rather than directional flow. Although directional data was considered during data collection, the analysis focused on understanding traffic composition and magnitude rather than movement patterns.

### 4.4.1 Overview of traffic conditions: Observation and Analysis

Oxford Street in East London is a key private and public transportation corridor, experiencing significant congestion during peak hours. The street accommodates various modes of transport, including private vehicles, minibus taxis, buses, and pedestrians. The researcher’s observations reveal critical issues contributing to traffic congestion, including high private vehicle usage, illegal stopping by public transport, disregard for traffic rules, and the impact of the taxi rank on overall traffic flow.

A high number of private vehicles leads to excessive road occupancy, reducing space for public transport and pedestrians, as illustrated in Figure 4.20. Insufficient road capacity and a lack of proper traffic management strategies exacerbate congestion. Limited use of alternative transport options, such as cycling or public transit, further increases vehicle dependency.

Public transport vehicles, including minibus taxis and buses, stop in undesignated areas, disrupting smooth traffic flow as illustrated in Figure 4.21. This behaviour leads to vehicle queuing, sudden stops, and potential safety risks for passengers and pedestrians. The lack of adequate loading and offloading zones contributes to these traffic violations.

Drivers often ignore traffic regulations, including no-stopping zones and pedestrian crossings, leading to road safety hazards as illustrated in Figure 4.22. Illegal parking, U-turns, and failure to yield further complicate movement along the corridor. The absence of strict enforcement encourages continuous non-compliance with traffic rules.

The minibus taxis operating from the taxi rank contribute to congestion, especially during peak hours. Taxis frequently stop abruptly to pick up and drop off passengers, causing delays and obstructing other road users, as demonstrated in Figure 4.23. The rank's proximity to the main road results in overflow congestion as taxis wait for passengers or manoeuvre into traffic.

**Figure 4. 20: Private vehicles**

**Figure 4. 21 Illegal offloading of passengers**

**Figure 4. 22: Disregarding traffic rules**

**Figure 4. 23: Heavy traffic flow due to the presence of a taxi rank**

Poor traffic regulation enforcement, high private vehicle usage, and inadequate transport infrastructure primarily cause the observed traffic congestion. The private vehicles lead to inefficient road usage, while illegal stopping and disregard for rules exacerbate delays. The taxi rank further adds to congestion by restricting vehicle movement and increasing pedestrian activity in the roadway. Without proper intervention, these issues will continue to degrade mobility, safety, and road efficiency on Oxford Street.

### 4.4.2 North End & Oxford Street Intersection

Table 4.1 shows the traffic situation at the North End & Oxford Street intersection as surveyed from 10th July 2023 to 16th July 2023, with a 16-hour traffic count per day. A total of 187,436 vehicles on the road during the week were recorded. Day-to-day variations in traffic patterns are evident, with weekdays typically exhibiting higher volumes than weekends.

Passenger cars make up most of the traffic, accounting for 180,901 of the total 187,436 vehicles for the entire week. This indicates that the area is heavily used by private cars, which could impact congestion. The highest count was recorded on Monday (48,249 vehicles), followed by Friday (48,656 cars). Monday and Friday are the busiest days, likely due to people returning to work at the start of the week and leaving for the weekend. This is particularly visible in passenger car data.

On Wednesday, July 12, 2023, there was a notable decrease in traffic (25,570 passenger cars), which may be a sign of lighter traffic during the week. A comparatively calmer midweek period is evident in other vehicle categories as well. The lowest total traffic count (9,336 vehicles) was recorded on Sunday, 16 July 2023, with 8,242 passenger cars. This might be because fewer people work or commute on Sundays. Interestingly, light trucks and motorcycles displayed more stable numbers throughout the week than other categories.

With only minor variations throughout the week, the number of minibuses and taxis was comparatively constant at 1,425 vehicles. These Figures indicate a steady need for the region's taxi services and public transportation. Heavy buses and light trucks remained consistent throughout the week, most likely due to local logistics and public transportation. Many delivery and service vehicles are present, as indicated by the light truck total (2,584).

Medium and heavy trucks had lower totals, with medium trucks being relatively consistent throughout the week. Heavy trucks peaked on Monday and Wednesday, with lighter traffic on other days, totalling 324 over the week. Motorcycles had moderate fluctuations, with the highest count on Tuesday (139) and the lowest on Wednesday (107). Motorcycles could be impacted by weather or events that affect two-wheeled transportation.

The fluctuation between weekdays and weekends can provide valuable insights into traffic congestion management. Lower weekend traffic may suggest less demand for public transport, allowing for potential shifts in transportation resources. The relatively consistent traffic from minibuses & taxis, and heavy buses indicates that public transport plays an essential role in the movement of people, especially on weekdays. Local authorities could improve public transport availability and efficiency during peak times, such as Monday and Friday. The traffic count information gathered at the intersection of Oxford Street and North End Street is shown in Table 4.1.

The analysis suggests a need for integrated transport solutions, including better public transit options and infrastructure adjustments, to address the challenges of high commuter volumes, especially during peak periods, using quantum flow theory. A balanced approach to optimising traffic flow and encouraging sustainable transportation could improve mobility and reduce congestion at the North End & Oxford Street intersection.

**Table 4. 1: Weekly traffic volume**

| **Location: Oxford Street - North End Street** | | | | **Date: 10/7/23 - 16/7/23** | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | **Traffic count duration: 16 hours** | | | | |
| **Category** | **Monday 10/7/23** | **Tuesday 11/7/23** | **Wednes -day 12/7/23** | **Thursda y 13/7/23** | **Friday 14/7/23** | **Saturda y 15/7/23** | **Sunday 16/7/23** | **Total** |
| Passenger cars | 48249 | 45716 | 25570 | 27522 | 48656 | 25195 | 8242 | 180901 |
| Minibuses & taxis | 212 | 249 | 186 | 252 | 236 | 259 | 243 | 1425 |
| Heavy buses | 72 | 107 | 80 | 72 | 80 | 73 | 80 | 492 |
| Light trucks | 421 | 440 | 413 | 425 | 447 | 429 | 430 | 2584 |
| Medium trucks | 201 | 173 | 157 | 157 | 157 | 170 | 150 | 964 |
| Heavy trucks | 76 | 57 | 46 | 55 | 55 | 53 | 58 | 324 |
| Motorcycle | 125 | 139 | 107 | 107 | 134 | 126 | 133 | 746 |
| **Total** | **49356** | **46881** | **26559** | **28590** | **49765** | **26305** | **9336** | **187436** |

*Traffic Count Data. (2023, July 10–16). Oxford Street – North End Street*

### 4.4.3 Caxton & Oxford Street intersection

The traffic volume at the intersection is captured by the traffic count data in Table 4.2 below, which covers 16 hours per day from Monday, 17 July 2023, to Sunday, 23 July 2023. Significant data about the transportation dynamics of East London can be gleaned from the traffic count data at the Caxton and Oxford Street intersection. The analysis identifies several significant trends and patterns to guide traffic management and urban planning plans. The key findings and analysis drawn from this data are examined below.

With 277,562 vehicles recorded during the week, passenger cars account for most of the traffic volume. Every day, they continuously make up the majority of all traffic. With 61,234 passenger cars, Friday, 14 July 2023, had the highest daily count. With 20,234 vehicles, Sunday, 16 July 2023, had the lowest daily count. This decrease might be a sign of less weekend commuter traffic. As is common at urban intersections in business districts where private vehicles are driven by daily commuters, locals, and tourists, the number of passenger cars is significantly greater than that of other vehicle types.

The number of minibuses and taxis was comparatively small and fluctuated, from 252 on Thursday to 1,576 on Friday. They appear to be more common on weekdays, particularly Fridays. This might result from increased passenger transportation on weekdays or during busy business days. Their variations, particularly the peak on Friday, might indicate the area's reliance on shared or public transportation. Taxi and minibus activity is higher on weekdays, especially Fridays. This may be because more people need transportation during the last few hours of the workweek.

The number of heavy buses ranged from 52 on Sunday to 101 on Monday, with a steady but modest volume. The Figures show comparatively steady bus traffic at the intersection because they don't vary much. This might be explained by intercity bus services or public transportation, given the urban location of the area. Light trucks, which range from 185 on Saturday to 428 on Monday, are essential for business operations and logistics. The counts seem relatively stable, with a minor decline over the weekend, which could indicate fewer deliveries or business on Saturdays and Sundays. On the other hand, traffic for medium trucks is moderate, ranging from 136 on Saturday to 201 on Tuesday. Their regular appearance suggests that there is continuous business or delivery traffic all week long.

Heavy trucks varied from 36 on Sunday to 222 on Friday. This Friday peak might indicate that more delivery or industrial trucks are coming into the area at the beginning or end of the workweek. The weekend decline might indicate fewer construction or industrial operations on Saturdays and Sundays. The increase in trucks on Friday points to a commercial or logistics-oriented function at the intersection, as companies may be preparing for operations or restocking over the weekend.

The number of motorcycles on the road decreased from 139 on Monday to 40 on Sunday. The trend points to fewer motorcycles on weekends, which could result from fewer commuters or people riding for fun on days other than work. The decline on weekends may also suggest that motorcycles are mainly used for daily commuting on weekdays, while on Sundays, fewer people use them for leisure.

The intersection's multipurpose role in supporting passenger cars, public transportation, and logistical operations is highlighted by the presence of all vehicle categories, from light trucks to buses and motorcycles. This implies that accommodating vehicles should be a factor in urban planning.

The decrease in traffic on weekends, particularly Sundays, indicates that although the intersection can manage fewer cars during these periods, preparing for weekday traffic spikes is still essential. Weekday traffic volumes are higher, which shows that traffic flow management needs to be optimised. Peak-hour congestion may be an issue, but improving public transit options and implementing traffic control strategies based on quantum flow theory may help ease the strain on this intersection.

According to urban planners and traffic management authorities, this data emphasises the need for targeted traffic control and planning strategies, particularly on busy days like Monday and Friday, and for allowing for private and shared transportation options in the area.

**Table 4. 2: Weekly traffic volume**

| Location: Oxford Street - Caxton Street | | | | Date: 17/07/2023 - 23/07/2023<br>Traffic count duration: 16 hours | | | | |
|---|---|---|---|---|---|---|---|---|
| **Category** | **Monday 10/7/23** | **Tuesday 11/7/23** | **Wednesday 12/7/23** | **Thursday 13/7/23** | **Friday 14/7/23** | **Saturday 15/7/23** | **Sunday 16/7/23** | **Total** |
| Passenger cars | 52456 | 49657 | 41524 | 47234 | 61234 | 25457 | 20234 | **277562** |
| Minibuses & taxis | 423 | 545 | 758 | 252 | 1576 | 250 | 182 | **3804** |
| Heavy buses | 101 | 72 | 81 | 72 | 80 | 56 | 52 | **462** |
| Light trucks | 428 | 421 | 254 | 425 | 413 | 185 | 190 | **2126** |
| Medium trucks | 164 | 201 | 170 | 157 | 157 | 136 | 94 | **985** |
| Heavy trucks | 203 | 198 | 74 | 67 | 222 | 38 | 36 | **802** |
| Motorcycle | 139 | 125 | 117 | 107 | 107 | 75 | 40 | **670** |
| **Total** | **53914** | **51219** | **42978** | **48314** | **63789** | **26197** | **20828** | **286411** |

*Traffic Count Data. (2023, July 17–23). Oxford Street - Caxton Street,*

### 4.4.4 Union & Oxford Street intersection

Understanding the flow and congestion of urban areas largely depends on traffic analysis, particularly during peak times like pay weeks when various economic activities usually result in higher than usual traffic volumes. Table 3 shows the traffic situation at the Union & Oxford Street intersection as surveyed from 24$^{th}$ to 30$^{th}$ July 2023, with a 16-hour traffic count per day.

The traffic count data gathered for the East London Central Business District is examined in this analysis, with a special emphasis on Oxford Street and Union Street. Insights into the transportation patterns and traffic behaviour during this peak period were obtained by measuring a variety of vehicle categories during a busy pay week. The traffic count data, such as motorcycles, light trucks, medium trucks, heavy trucks, passenger cars, minibuses and taxis, and heavy buses, cover numerous important vehicle categories. Key trends, days with heavy traffic, and how different vehicle types affect the overall traffic situation are all included in the analysis.

With 69,863 vehicles across all categories, Friday, 28 July 2023, saw the highest traffic volume. It is common for people to increase their shopping, commuting, and other activities during pay weeks. The significant reliance on private vehicles during this time is indicated by the rise in passenger cars (65,982). Throughout the week, passenger cars comprised most vehicles on the road, with 405,678 total by the end of the seven days. Because of its accessibility and convenience, private transportation is probably the most popular form of transportation in this area during peak hours, as evidenced by the large number of passenger cars.

With 2,304 vehicles registered on Friday, 28 July 2023, minibuses and taxis showed a discernible increase. This rise can be explained by a greater demand for public transportation during hectic pay weeks, as more people might take minibuses and taxis rather than drive or deal with parking during rush hour. The percentage of heavy buses (such as city buses) in the overall traffic was lower. On busy days, such as Thursday, 27 July 2023, the number of vehicles reached 234. The buses in the area demonstrate the necessity for public transportation systems to accommodate the high passenger demand, especially for commuters and shoppers.

Light, medium, and heavy trucks add to traffic; on Friday, 28 July 2023, the number of medium trucks was 435. Commercial operations in the central business district, such as delivery and logistics, are probably the leading cause of the trucks' presence.

Despite being a smaller category than passenger cars, motorcycles still accounted for a sizable portion of traffic. On Tuesday, 25 July 2023, the number of motorcycles reached its highest point with 156 vehicles. For those who prefer to eat online, restaurants frequently favour motorcycles because of their capacity to handle heavy traffic, particularly in urban settings.

With 31,085 vehicles overall, Sunday, 30 July 2023, saw a sharp drop in traffic volume compared to other days. This aligns with typical city trends, where traffic tends to slow down on weekends, especially on Sundays when businesses and commercial activity decline.

The traffic count data reveal significant patterns in urban mobility gathered during a busy pay week in East London's central business district, focusing on Oxford Street and Union Street. These patterns reflect the community's transportation preferences and economic activity. Indicating the impact of economic activity and the hectic nature of pay weeks, passenger cars continuously dominated the traffic, with Friday being the busiest day. The increase in medium trucks, minibuses, and taxis further emphasises the rise in traffic driven by logistics and public transportation. Sunday's lower traffic volume confirms usual weekend patterns in urban traffic.

The traffic data highlights typical urban traffic patterns, with higher volumes during weekdays, especially Fridays, and a noticeable decrease in Sunday traffic. The dominance of passenger cars suggests that road infrastructure needs to be optimised for high-volume, everyday traffic. The patterns for public transport vehicles (minibuses and taxis) and commercial vehicles (trucks and buses) reflect the economic activities that drive demand for these services. Traffic planning and road maintenance should consider these fluctuations in volume, especially on weekdays versus weekends, to ensure smoother traffic flow and minimise congestion during peak times.

**Table 4. 3: Weekly traffic volume**

| **Location: Oxford Street - Caxton Street** | | | | **Date: 24/07/2023 - 30/07/2023**<br>**Traffic count duration: 16 hours** | | | | |
|---|---|---|---|---|---|---|---|---|
| **Category** | **Monday 24/7/23** | **Tuesday 25/7/23** | **Wednesday 26/7/23** | **Thursday 27/7/23** | **Friday 28/7/23** | **Saturday 29/7/23** | **Sunday 30/7/23** | **Total** |
| Passenger cars | 64767 | 62789 | 60562 | 61672 | 65982 | 59672 | 30234 | **405678** |
| Minibuses & taxis | 578 | 657 | 745 | 890 | 2304 | 1678 | 250 | **7102** |
| Heavy buses | 145 | 167 | 189 | 234 | 289 | 123 | 68 | **1215** |
| Light trucks | 428 | 421 | 254 | 395 | 413 | 185 | 190 | **2286** |
| Medium trucks | 234 | 278 | 300 | 345 | 435 | 403 | 156 | **2151** |
| Heavy trucks | 145 | 264 | 262 | 264 | 278 | 201 | 98 | **1512** |
| Motorcycle | 141 | 156 | 150 | 142 | 162 | 130 | 89 | **970** |
| **Total** | **66438** | **64732** | **62462** | **63942** | **69863** | **62392** | **31085** | **420914** |

*Traffic Count Data. (2023, July 24–30). Oxford Street – Union Street*

## 4.5 Analysis on Traffic Count and Questionnaire using Quantum Flow Theory

The technical problems noted in the traffic count analysis can be directly linked to the questionnaire results, which offer insightful information about public transportation preferences, transportation behaviours, and factors contributing to traffic congestion, along with traffic control analysis using QFT. The integration of QFT provides a sophisticated methodology to accurately interpret large data sets in the context of traffic count and questionnaire data analysis. In contrast to questionnaire data, which captures the human elements of traffic behaviour, like driver preferences and attitudes, traffic count data usually entails collecting information about vehicle volume. An integrated analysis of these connections is presented in the following section.

### 4.5.1 Impact of car ownership on traffic congestion

According to the questionnaire, many participants used passenger cars as drivers and passengers (27.3% and 25.3%, respectively), indicating a firm reliance on personal vehicle ownership. According to the traffic count data, this high reliance on private vehicles is one of the leading causes of traffic congestion.

According to traffic count data, passenger cars predominate at major intersections such as North End & Oxford Street, Caxton & Oxford Street, and Union & Oxford Street. According to the results of the questionnaire, the majority of the vehicles recorded were passenger cars (e.g., 180,901 vehicles in North End & Oxford Street and 277,562 vehicles at Caxton & Oxford Street). According to the survey, there is a direct correlation between the high number of passenger cars and the rise in car ownership, which fuels traffic during peak hours (such as Mondays and Fridays).

### 4.5.2 Impact of Public Transportation (PT) on traffic congestion

The survey's high preference for private vehicles indicates dissatisfaction with public transportation. According to the study, the preference for private cars over public transportation results from East London's poor public PT system. People are frequently forced to rely on their private vehicles due to the limited availability and inadequate quality of public transportation, which worsens traffic congestion.

The traffic count also reflects the varying usage of taxis and minibuses. Minibuses and taxis, for instance, had comparatively constant numbers during the week (for example, 1,425 minibuses and taxis at North End & Oxford Street). Still, they were far fewer than the number of passenger cars. Compared to passenger cars, the low use of public transportation highlights the shortcomings in PT service.

The survey's findings that public transportation is used more frequently on peak days or during special events are consistent with the higher usage of minibuses and taxis on Fridays. This suggests a growing need for better public transportation options to reduce car reliance.

### 4.5.3 The key factors contributing to traffic congestion

High traffic volume, a lack of parking spaces, careless driving, unlawful passenger loading and unloading, and poor road infrastructure are some of the leading causes of traffic congestion identified by the questionnaire. These results are consistent with the technical problems found in the traffic count analysis.

The traffic counts make it abundantly evident that the large volume of passenger vehicle traffic is a major contributor to congestion. The high vehicle density at critical intersections (such as Caxton & Oxford Street and North End & Oxford Street), where traffic volume peaks during the week, indicates the inadequate road infrastructure. Similarly, illegal passenger loading, unloading, and parking congestion cause bottlenecks at some intersections by forcing cars to stop or slow down, affecting traffic flow.

### 4.5.4 Integrated traffic management measures

According to the survey, carpooling (84.11%), better public transportation (78.91%), and traffic signal optimisation (83.90%) were the most common methods to reduce traffic congestion. These measures address the fundamental problems of excessive private vehicle use and ineffective public transportation infrastructure.

The traffic count analysis supports these findings. For example, the steady presence of taxis, light trucks, and minibuses points to the necessity of better coordinating public transportation services to meet peak demand and the possible advantages of carpooling programs. Similarly, the quantum flow theory would directly aid in optimising traffic signals by improving signal timing based on real-time traffic data, guaranteeing smoother movement for all vehicles.

### 4.5.5 Impact of parking and road infrastructure

A sizable portion of survey participants (74.74%) cited a lack of parking spaces as a primary cause of traffic delays. This is consistent with the traffic count data, which shows that the traffic volume is excessively high for the available infrastructure. High vehicle counts in locations with limited parking availability draw attention to the problem of insufficient parking spaces. Traffic bottlenecks are created when vehicles are forced to slow down due to illegal parking and congestion near parking lots.

### 4.5.6 Quantum Flow Theory for enhanced traffic management

Understanding the quantum nature of traffic and optimising vehicle flow rates and spatial distribution are two ways QFT can create efficient traffic flow. Based on their overwhelming presence in the traffic count data, private vehicles appear to be a major contributor to traffic congestion. Based on the quantum probabilities of vehicle movements, QFT could improve road usage, control traffic flow density, and optimise traffic light timings, particularly during peak hours.

According to QFT, examining the dynamics of vehicle movements under various circumstances can help optimise transportation networks. Lowering passenger wait times and modifying bus and minibus frequency could be used to increase the effectiveness of public transportation. Furthermore, by optimising how private and public transportation share the road network, quantum-based traffic control mechanisms may aid in the more seamless integration of both modes of transportation and help to lessen overall congestion.

Traffic flow through urban infrastructure can be modelled using QFT, which can also forecast bottlenecks brought on by high vehicle density. By analysing the quantum probabilities of congestion patterns, QFT may help regulate illegal loading and unloading, curb reckless driving, and improve traffic flow at bottleneck-prone intersections by informing vehicle routing and traffic signal timings.

QFT may help optimise vehicle flow management and signal timing with improved quantum-based traffic pattern predictions. To enhance overall congestion management, QFT may help dynamically modify traffic signal timings, decrease delays, and enable more effective distribution of road space to high-density traffic areas (like public transportation routes) by analysing the probabilistic nature of traffic flow.

Using QFT, parking management strategies can be developed, and the dynamics of vehicle flow around parking areas can be better understood. Better urban planning, signal modifications, and vehicle routing can all be informed by QFT, which forecasts traffic congestion brought on by inadequate parking.

## 4.6 Correlation interpretation and analysis

### 4.6.1 Correlation analysis on factors contributing to traffic congestion

This section uses Spearman's rank correlation coefficient (Spearman's rho) to analyse the relationship between on-street parking, high traffic volume, illegal passenger loading and unloading, and limited parking space. The objective is to examine the direction and strength of the relationships between these variables and determine their significance.

There is a weak but significant correlation ($\rho = 0.154$, $p = 0.003$) between high traffic volume and a lack of parking spaces. This implies that other factors influence traffic volume, even though parking restrictions may be a contributing factor. Limited parking spaces are moderately correlated with illegal passenger loading and unloading ($\rho = 0.303$, $p < 0.001$), suggesting that a lack of designated parking areas may encourage unauthorised passenger activities. Limited parking space and on-street parking have a moderate correlation ($\rho = 0.318$, $p < 0.001$), indicating that a lack of parking facilities causes cars to stop or park illegally along the road.

Congestion may contribute to unauthorised stopping for passenger drop-offs and pick-ups, as evidenced by the weak correlation between high traffic volume and illegal passenger loading/unloading ($\rho = 0.174$, $p = 0.001$). On-street parking and high traffic volume have a weak correlation ($\rho = 0.275$, $p < 0.001$), indicating that although roadside parking is associated with congestion, other factors such as land use and enforcement contribute.

Illegal passenger loading, unloading, and on-street parking correlate strongly (ρ = 0.598, p < 0.001). This suggests a close connection, with unapproved passenger activity playing a significant role in traffic jams and safety hazards by causing cars to stop on the street.

**Table 4. 4: The illustration of correlation analysis**

**Correlations**

| | | | Limited parking space | High traffic volume | Illegal loading & unloading of passengers | On-street parking |
|---|---|---|---|---|---|---|
| Spearman's rho | Limited parking space | Correlation Coefficient | 1.000 | .154** | .303** | .318** |
| | | Sig. (2-tailed) | . | .003 | .000 | .000 |
| | | N | 384 | 384 | 384 | 384 |
| | High traffic volume | Correlation Coefficient | .154** | 1.000 | .174** | .275** |
| | | Sig. (2-tailed) | .003 | . | .001 | .000 |
| | | N | 384 | 384 | 384 | 384 |
| | Illegal loading & unloading of passengers | Correlation Coefficient | .303** | .174** | 1.000 | .598** |
| | | Sig. (2-tailed) | .000 | .001 | . | .000 |
| | | N | 384 | 384 | 384 | 384 |
| | On-street parking | Correlation Coefficient | .318** | .275** | .598** | 1.000 |
| | | Sig. (2-tailed) | .000 | .000 | .000 | . |
| | | N | 384 | 384 | 384 | 384 |

**. Correlation is significant at the 0.01 level (2-tailed).

In correlation analysis, several key values are used to interpret the relationships between variables. Below is a brief explanation of each:

- **Spearman's rho (ρ):** Measures the strength and direction of the relationship between two variables (ranges from -1 to +1).
- **Correlation Coefficient:** Represents the strength and direction of the relationship between two variables. Closer to +1 or -1 means a stronger relationship (positive or negative, respectively). Closer to 0 indicates a weaker or no relationship between the variables.
- **p-value (Sig. 2-tailed):** Indicates statistical significance (p < 0.05 means the correlation is likely meaningful, while p > 0.05 suggests the correlation might not be significant and could have occurred by chance.
- **N (Sample Size):** The number of observations used in the analysis (higher N improves reliability).

## 4.7 Conclusion

The East London mobility study reveals that growing reliance on private vehicles and inadequate public transportation has led to significant traffic congestion, particularly during peak hours. Taxis and ridesharing are the most popular forms of transport, but the inefficiency and inaccessibility of public transit have pushed more people to use private cars, worsening the traffic situation. Factors such as high traffic volumes, lack of parking, unlawful passenger loading, and poor road infrastructure contribute to the delays. In contrast, driver behaviour and disregard for traffic laws exacerbate the problem. This negatively impacts commuters' well-being, including exhaustion, annoyance, and stress.

The study recommends a comprehensive approach to improving infrastructure, traffic management, and public transportation systems to alleviate these issues. Strengthening bus networks, enforcing stricter traffic laws, and enhancing road designs could significantly reduce congestion. Addressing these challenges is essential to improving mobility, supporting economic growth, and enhancing the overall quality of life in East London.

The traffic analysis along Oxford Street in East London reveals significant congestion, driven primarily by passenger cars, especially on weekdays, with peak traffic observed on Mondays and Fridays. Public transportation, including minibuses, taxis, and buses, remains stable but experiences higher demand on Fridays, likely due to increased weekend preparation. Weekend traffic, particularly on Sundays, is noticeably lower, suggesting opportunities for optimising transport resources during off-peak hours. Economic activity also influences traffic flow, with an apparent increase in congestion around pay weeks, highlighting the connection between urban mobility and economic cycles.

The report recommends exploring integrated transport solutions, including enhanced public transportation options, optimised infrastructure, and innovative traffic management strategies to reduce congestion and improve traffic flow. A balanced approach that encourages sustainable transport while addressing peak-hour challenges would better accommodate East London's growing population and economic activity, making the transport network more efficient and accessible.

Integrating Quantum Flow Theory (QFT) with traffic count and questionnaire analysis provides a comprehensive approach to understanding and managing urban traffic congestion. The results show a high reliance on private automobiles, which is made worse by a lack of parking spaces and a poor public transit system. The analysis also reveals critical congestion factors like high vehicle density, unlawful loading and unloading, and ineffective traffic management at essential intersections.

Through better vehicle distribution, dynamic signal adjustments, and increased public transportation efficiency, traffic flow can be optimised using QFT. Better parking space allocation, better traffic signal timing, and optimised carpooling incentives are just a few of the more efficient congestion mitigation techniques made possible by probabilistic modelling of vehicle movements. These revelations highlight the necessity of a comprehensive approach to traffic management that combines cutting-edge mathematical modelling with functional infrastructure upgrades. A more sustainable and effective urban transportation system may result from combining data-driven analysis and QFT-based optimisation.

# CHAPTER 5 : CONCLUSION AND RECOMMENDATIONS

## 5.1 Introduction

This section serves as the culmination of the study on traffic congestion along Oxford Street in East London (EL), presenting its findings and corresponding recommendations. It begins by revisiting the conceptualisation of research challenges and objectives outlined in Chapter One. Subsequently, Chapter Two examines techniques for reducing traffic jams within the urban transportation system. Chapter Three elucidates the chosen research approach, providing insights into the methodology. Chapter Four, meanwhile, delves into the presentation of quantitative results derived from the study's data analysis.

This concluding chapter expounds upon integrating literature with the study's findings, alongside a comprehensive presentation of quantitative findings, recommendations, and conclusions. In addition, it delineates directions for future investigation, capturing the extensive course of the study from inception to completion.

## 5.2 Summary of Findings

This segment synthesises the synopsis and conclusions of the current study, deriving insights from the literature review and the quantitative analysis conducted through chapters two, three, and four. The data analysis findings are carefully examined about the research objectives. To augment the aim of the study, the research objectives are meticulously inspected, aligning the quantitative findings with the overarching goals of the investigation.

From the comprehensive analysis conducted, the following conclusions emerge:

### 5.2.1 Objective 1 and 2: Findings

The study's findings unveiled several factors contributing to the daily traffic congestion experienced by users of Oxford Street. These include elevated traffic volume, scarcity of parking spaces, instances of reckless driving, and non-compliance with traffic regulations. The surge in car ownership, propelled by economic expansion and compounded by insufficient public transport infrastructure, exacerbates the issue.

Drivers traversing the EL-CBD grapple with delays, frustration, and financial setbacks resulting from congested thoroughfares and degrading air quality. Identifying the congested areas, particularly the three primary intersections of Oxford Street, is imperative for implementing mitigation strategies to ensure sustainability, optimise traffic flow, and foster safe mobility across the transportation network.

Aligned with the objectives of the current study, the findings underscore the necessity of introducing carpooling initiatives and promoting their uptake among EL residents for daily commuting. Enhancing public transport efficiency, implementing parking management strategies, synchronising traffic lights for effective traffic control, and instituting a well-coordinated local bus service are viable measures to ameliorate traffic flow along Oxford Street.

Furthermore, the study delineates distinct peak periods of road traffic congestion on Oxford Street, typically from 6:00 to 10:00 in the morning and from 2:00 to 6:00 p.m. These findings affirm that congestion on Oxford Street is relatively subdued outside these specified timeframes, barring exceptional circumstances such as accidents or special events, which may sporadically disrupt traffic flow.

### 5.2.2 Aim of the research

Based on the research objectives and their corresponding results, several conclusions can be drawn to fulfil the aim of the study, which focused on assessing capacity analysis and optimising traffic flow to promote safe mobility along the East London Central Business District's (EL-CBD) Oxford Street, employing quantum flow theory at three key intersections. The comprehensive findings underscore that the management of road traffic congestion along Oxford Street in East London is currently suboptimal, primarily attributable to deficiencies in service management. Moreover, the study identifies various strategies to address these congestion challenges, including promoting carpooling, enhancing public transport efficiency, reinforcing parking management protocols, synchronising traffic signals for effective traffic control, and bolstering local bus services.

The study advocates implementing operational improvements to actualise these strategies and bolster traffic flow optimisation and safe mobility. These measures encompass active traffic management facilitated by traffic officers, fine-tuning of traffic signal timing and coordination, efficient incident management protocols, and the provision of mass public transportation options. By adopting these strategies, the study posits that traffic congestion mitigation efforts will be fortified and supported, fostering enhanced traffic flow management along Oxford Street.

## 5.3 Research Contributions

East London (EL) stands as one of the urban centres grappling with the pervasive issue of traffic congestion, and the current research endeavour contributes substantially to the existing body of knowledge on this subject. Notably, this study represents a significant advancement in understanding, as no prior empirical investigation specifically addresses traffic congestion along Oxford Street. By filling this notable research gap, the study serves as a crucial resource for local and provincial road authorities, decision-makers, and transportation planners, offering valuable insights and recommended solutions to mitigate the challenges posed by mobility issues within the region.

## 5.4 Recommendations

According to the study, several obstacles prevent Oxford Street in EL from being completely traffic-free. The study found that ineffective parking management, contempt for traffic laws, and dangerous driving habits all contribute to dysfunctionality in the law enforcement agency. You see cars parked where parking is prohibited along EL's Oxford Street. Due to the lack of interaction of motorists with the road markings and signage, drivers frequently violate traffic laws and regulations. The recommended actions are listed below.

The recommendations below are based on a detailed technical analysis of traffic volumes, congestion patterns, and road user behaviour along Oxford Street and at the three analysed intersections (North End, Caxton, and Union Street). Each recommendation is tailored to address specific issues identified in the study, including congestion patterns, vehicle type distribution, and peak-hour trends.

Proposed infrastructure and traffic management measures aim to enhance mobility, safety, and efficiency in EL's CBD.

### 5.4.1 Reduction of private car ownership usage

A significant reduction in private car ownership and usage is necessary to alleviate traffic congestion in EL's CBD. This shift can be achieved through strategic urban planning, improved public transport systems, incentivising sustainable transportation options, and public policy measures like congestion pricing. By reducing the dominance of private cars on the road, the city can foster a more efficient, environmentally friendly, and liveable urban environment for all residents and visitors.

It is frequently assumed by current recommendations that commuters will easily switch from private vehicles to public transportation. However, because of problems like poor intermodal connectivity, infrequent service schedules, safety concerns, and limited route coverage, EL's current public transit systems continue to be underutilised. Due to these obstacles, private car ownership is maintained, and widespread adoption is discouraged.

A focused strategy that increases service accessibility and dependability, boosts comfort and safety, and incorporates multiple transportation options to provide a smooth commute is needed to address this. Employer-sponsored transit incentives, fare subsidies, and public education initiatives can promote a modal shift. The city can develop a competitive and appealing substitute for private vehicle ownership by addressing the underlying causes of underutilisation, ultimately fostering a more effective, sustainable, and liveable urban environment.

### 5.4.2 Enhancing public transit and promoting shared mobility

Public perception strongly supports public transit improvements as a solution to congestion, with 78.91% of respondents advocating for increased efficiency and 66.93% favouring local bus services. Addressing these needs requires a comprehensive approach integrating accessibility, technology, and policy-driven incentives to shift commuter behaviour towards sustainable transportation.

**Enhancing accessibility and connectivity:** To encourage public transit adoption, accessibility must be improved through well-integrated, multimodal solutions. Investments in micro-mobility options such as e-scooters, bike-sharing, and mini-buses will facilitate first- and last-mile travel, reducing dependence on private vehicles. Traffic management authorities should prioritise seamless integration between buses, trains, and shared mobility services to minimise transfer delays and improve user convenience. Additionally, expanding Bus Rapid Transit (BRT) networks and increasing dedicated taxi lanes during peak hours will enhance service efficiency and mitigate congestion.

**Flexible, demand-responsive transit services:** Public transit must adapt to varying commuter needs by implementing dynamic, on-demand services where shuttles or buses operate based on real-time requests, particularly in lower-demand areas. Extending transit operating hours, including early mornings, late nights, and weekends, will also ensure accessibility for individuals with non-traditional work schedules. Intelligent scheduling based on real-time demand tracking will further optimise bus and minibus routes, improving overall efficiency.

**Leveraging technology and sustainability:** Modernising public transportation through technology is key to boosting adoption. Investments in electric buses, green infrastructure, and sustainable transit solutions will make public transport more environmentally friendly and appealing. Additionally, real-time tracking apps and integrated ticketing systems will streamline the user experience, allowing commuters to plan trips, make payments seamlessly, and monitor vehicle arrivals. A unified ticketing system connecting various transport modes, including public transit, shared mobility, and private vehicles, will enhance convenience.

**Encouraging Carpooling and High-Occupancy Travel:** Since 92.45% of respondents identified private vehicle usage as a major contributor to congestion, promoting shared mobility is essential. To achieve this:

- High-Occupancy Vehicle (HOV) lanes should be implemented along Oxford Street, prioritising vehicles with two or more occupants.
- Carpool pickup zones should be designated near high-traffic intersections to facilitate shared rides.

- Incentives such as discounted tolls and preferred parking should be introduced to encourage carpooling.
- Public transport efficiency should be enhanced by increasing bus frequency along Oxford Street during peak congestion hours (6:00–10:00 AM and 2:00–6:00 PM).
- New bus stops should be installed at high-demand locations to improve accessibility and ease congestion near key intersections.
- By integrating these strategies, enhancing public transit accessibility, adopting flexible services, leveraging technology, and promoting shared mobility, urban congestion can be effectively mitigated. A well-coordinated, multimodal transportation network will improve commuter convenience and create a more sustainable and efficient urban environment.

### 5.4.3 Park-and-ride (PNR) facilities

The research underscores the implementation of Park-and-Ride (PNR) amenities as a pivotal strategy in mitigating the prevailing transportation challenges. PNR systems are strategically devised to alleviate urban traffic congestion by incentivising private vehicle owners to park their cars in designated lots on the periphery of urban centres and utilise public transportation for commuting into the Central Business District (CBD). While the primary objective of PNR systems is to dissuade personal vehicle usage, they concurrently contribute to traffic congestion reduction by promoting public transit utilisation for a portion of commuters' journeys.

However, it's worth noting that these facilities, reliant on drivers accessing their vehicles, may not sufficiently cater to the needs of the most vulnerable demographic segments of the population. Nevertheless, PNR systems effectively incentivise mode-shift by facilitating vehicle utilisation for specific journey segments, particularly in low-density peripheries or metropolitan fringes, where transitioning to public transit offers respite from traffic congestion and exorbitant parking fees. To foster a smoother transition for car users towards adopting PNR services, it is imperative to strategically position appealing facilities equipped with an array of incentives within accessible locales.

### 5.4.4 Reinforcement of law enforcement initiatives

Several behavioural and structural issues significantly influence traffic congestion in the EL-CBD. Reckless driving (73.96%), illegal loading and unloading of passengers (72.14%), disregard for traffic rules (67.71%), and on-street parking (64.58%) all contribute to disruptions in traffic flow. Addressing these issues necessitates a robust and well-coordinated law enforcement strategy by reinforcing the National Road Traffic Law Enforcement Code (NRTLEC).

**Reckless driving (73.96%):** The high occurrence of reckless driving requires stricter monitoring and enforcement of traffic laws. Deploying traffic officers at high-risk intersections, implementing automated ticketing systems, and utilising traffic cameras for real-time monitoring can deter reckless behaviour and enhance road discipline.

**Illegal loading and unloading of passengers (72.14%):** Unregulated stops by taxis and public transport vehicles create bottlenecks. Reinforcement of law enforcement can include stricter penalties for violations, designated loading zones, and continuous surveillance to ensure compliance. Standardised training for officers will enable them to handle such violations effectively.

**Disregard for traffic rules (67.71%):** A lack of adherence to traffic regulations exacerbates congestion. To counteract this, the NRTLEC prioritises proactive law enforcement, public education campaigns, and standardised enforcement procedures. Automated ticketing for common violations such as illegal parking, running red lights, and speeding will ensure compliance without excessive manual intervention.

**On-street parking (64.58%):** Unauthorised and excessive on-street parking reduces lane capacity, further contributing to congestion. Law enforcement officers must have clear protocols for ticketing and towing illegally parked vehicles. Additionally, urban planning collaboration can facilitate the development of alternative parking solutions to reduce street-level congestion.

The NRTLEC emphasises integrating technology, ongoing officer training, and public awareness campaigns to ensure sustainable improvements. Establishing feedback mechanisms for reporting violations and monitoring officer performance will reinforce traffic regulations and ensure accountability. By aligning enforcement strategies with identified congestion factors, the NRTLEC can effectively enhance traffic flow, road safety, and overall compliance within the EL-CBD.

### 5.4.5 Road expansion and smart infrastructure deployment

The analysis showed that inadequate road infrastructure (59.11%) contributes to traffic inefficiencies. Proposed measures include the following:

- Explore the feasibility of widening key sections of Oxford Street where congestion bottlenecks occur.
- Implement innovative traffic management technologies, such as AI-based traffic monitoring systems, to optimise vehicle movement and congestion prediction.
- Develop long-term urban planning strategies integrating multimodal transport options, including bicycle lanes and pedestrian-friendly zones.

### 5.4.6 Integrated transport planning (ITP)

To ensure equitable treatment across all transportation modes and segments within the freight and passenger transport sub-sectors, EL emphasises the importance of continuous integrated transport planning. This process, crucial for developing mobility within the EL-CBD, entails an interdisciplinary approach to devising the most efficient transportation system based on historical, present, and projected transit trends.

Initiating EL-CBD mobility development revolves around transportation planning, a multifaceted endeavour that integrates various disciplines to address transportation needs strategically. Implementing and promoting ITP in the EL-CBD will facilitate the management and facilitation of transportation planning, associated policies, and strategies. Furthermore, it will support economic modelling, sector analysis, and the coordination of regional and inter-sphere linkages.

Transportation planning incorporates land use considerations, policy formulation, funding mechanisms, and technological advancements to deliver comprehensive solutions. Before crafting plans, effective transportation planning entails a thorough examination of community needs, travel patterns, and demographics. This involves evaluating the current transportation system, estimating demand, and recommending improvements while considering financial constraints.

Through transportation planning, policymakers in EL can delineate city objectives by analysing demographics and travel patterns, thus anticipating future changes to inform policy formulation. Subsequent adjustments in spatial planning designs and investments can effectively accommodate evolving needs and urban mobility demands.

### 5.4.7 Enhancing traffic flow and reducing bottlenecks

Union & Oxford Street saw peak traffic volumes of 69,863 vehicles on Friday, 28 July 2023, showing that pay weeks significantly affect congestion. To mitigate this, traffic signal optimisation should be implemented at all three intersections to improve peak-hour flow, reducing wait times for both private and public transport. Left-turn lanes at North End & Oxford Street should be expanded, as heavy and medium trucks peak on Mondays and Fridays, affecting intersection efficiency. A roundabout feasibility analysis should be conducted at Union & Oxford Street to handle the extreme congestion observed during peak weeks.

### 5.4.8 Parking, loading, and pedestrian infrastructure management

Limited parking and illegal loading/unloading were highlighted as significant congestion factors, with 74.74% and 72.14% of respondents identifying them as major issues, respectively. Pedestrian movement, especially at crosswalks, significantly contributes to congestion. The study found that 58.33% of respondents identified frequent pedestrian crossings as a congestion factor. To address congestion caused by both limited parking and pedestrian movement, the following measures are proposed:

- Designate specific zones for taxi and bus passenger loading and unloading, clearly marked and enforced to prevent illegal stops.
- Introduce digital parking management systems, including real-time parking availability updates, to reduce unnecessary vehicle circulation.

- Implement stricter enforcement of parking regulations, particularly near intersections and bus stops, to prevent unauthorised street parking.
- Encourage the development of multi-story parking facilities to reduce on-street parking demand.
- Widen sidewalks in high-footfall areas and construct pedestrian overpasses or underpasses at major crossing points to facilitate smooth pedestrian movement and reduce road congestion.
- Improve lighting and signage at crosswalks, and redesign intersections to include designated pedestrian waiting zones, enhancing pedestrian safety and traffic flow.

### 5.4.9 Traffic management strategies based on Quantum Flow Theory (QFT)

Based on the traffic count analysis at the key intersections of Oxford Street in EL-CBD, a traffic control strategy informed by QFT is recommended to enhance traffic efficiency, minimise congestion, and improve overall urban mobility. Quantum Flow Theory, which models traffic as a dynamic, wave-like system influenced by density, velocity, and flow interactions, provides valuable insights into optimising traffic patterns and infrastructure utilisation.

The study recommends introducing an AI-driven adaptive traffic signal system that adjusts signal timing based on real-time traffic flow data, density waves, and queue lengths. This will smooth traffic fluctuations by allowing high-density vehicle groups to move efficiently while reducing idle time at intersections, particularly during Monday and Friday congestion peaks. This will result in Improved vehicle throughput, reduced waiting times, and lower emissions due to minimised stop-and-go traffic.

Dedicated High-Flow Lanes for Peak-Hour Passenger Traffic are necessary to alleviate traffic flow. Establishing dynamic lane control by designating reversible lanes and HOV lanes on Oxford Street and adjacent intersections to accommodate peak-hour traffic is recommended, as well as dedicating high-flow lanes for peak-hour passenger traffic. This will allow more efficient handling of passenger car waves, reducing congestion during high-flow periods. This will increase road capacity without expanding infrastructure, ensuring smoother traffic flow.

Employing empirical data from Oxford Street's traffic volume, speed variations, and density fluctuations to simulate wave propagation effects using QFT principles is recommended. It will analyse shockwave formations during peak hours (6:00–10:00 AM and 2:00–6:00 PM) to determine the propagation speed of congestion waves and optimise traffic management responses.

Applying QFT principles can establish an adaptive and dynamic traffic control system in EL's CBD. The city can reduce congestion, improve mobility, and enhance transport sustainability through AI-driven traffic signals, dedicated lanes, optimised public transport operations, and time-sensitive freight management. These measures ensure a balanced, flow-optimised transportation network that effectively accommodates all vehicle categories while mitigating traffic bottlenecks.

## 5.5 Propositions for Future Research

The current study endeavoured to analyse capacity and optimise traffic flow to bolster safe mobility along Oxford Street within the EL-CBD, leveraging quantum flow theory at three pivotal intersections. Employing a quantitative research approach, the study aimed to comprehensively understand the prevalent traffic congestion within EL, particularly focusing on Oxford Street. Quantitative findings underscore the imperative for further research into road traffic congestion management in SA. Subsequent investigations should scrutinise methodologies to eliminate traffic congestion on roadways, necessitating a permanent solution. Furthermore, it is suggested that the present survey be reiterated to furnish feedback to the provincial management or that a comparative analysis be undertaken to evaluate drivers' perceptions and responses to traffic congestion challenges.

To improve traffic flow forecasts and increase the flexibility of traffic management systems, it is advised that future studies investigate the integration of real-time data analytics with QFT. Furthermore, applying this strategy to other cities with comparable traffic problems may offer a more comprehensive understanding of the suitability and scalability of QFT in traffic control worldwide.

## 5.6 Conclusion

To fully address the study's objectives, the literature review concentrated on the morning and afternoon peak hours, methods for managing traffic congestion, and contributing factors. Supplementary objectives were developed to augment the research aim and ensure comprehensive data gathering and utilisation. The investigation effectively addressed these objectives, culminating in a nuanced understanding of the ramifications of traffic congestion.

In conclusion, this study offers a comprehensive analysis of traffic congestion in the East London Central Business District (EL-CBD), specifically along Oxford Street, through the innovative application of Quantum Flow Theory (QFT). By examining key intersections and analysing traffic patterns, the research identifies the primary factors contributing to congestion, including high private vehicle usage, inadequate public transportation, and behavioural issues like non-compliance with traffic regulations. The study highlights the peak congestion periods, particularly during work hours, and underscores the need for a balanced approach to urban traffic management.

The application of QFT provides a novel framework for optimising traffic flow, offering insights into more efficient signal timings, improved public transport systems, and better route planning. These findings support the development of an Integrated Transportation Plan (ITP), which promotes sustainable urban mobility by addressing both the demand for private vehicles and public transport supply. The proposed strategies, such as carpooling, optimised traffic management, and flexible work hours, show promise in alleviating congestion and enhancing urban mobility.

This research also acknowledges the uncertainties within transportation systems, such as unpredictable driver behaviour and infrastructure developments, which require adaptive planning and continual evaluation. Combining QFT-based insights and practical policy recommendations provides a strong foundation for improving traffic flow and overall urban mobility in EL. By applying these findings, EL can work towards a more efficient, safer, and sustainable transportation system, potentially applicable to other metropolitan areas facing similar congestion challenges.

The application of QFT could be expanded by integrating emerging technologies such as artificial intelligence (AI) and machine learning (ML) for real-time traffic analysis and dynamic traffic management. AI-driven systems could predict congestion patterns more accurately, enabling timely adjustments to signal timings, optimal route planning, and even the management of public transport capacity. This would lead to a more agile and responsive transportation system.

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# APPENDIX A: QUANTITATIVE QUESTIONNAIRE

**Traffic survey questionnaire**

**East London Oxford Street traffic management study**

**Contact details:**

Name (Optional): ……………………………………………

Address: ……………………………………………………...

Date: ………………………………………………………….

## SECTION A: BIODATA

**1. How long have you lived in East London?**

- I don’t live in East London. ☐
- Less than 1 year ☐
- 1 – 3 years ☐
- 3 – 6 years ☐
- 6 – 10 years ☐
- More than 10 years ☐

**2. What is your gender?**

- Male ☐
- Female ☐
- Other ☐
- Prefer not to answer. ☐

**3. How old are you?**

- Under 18 years ☐
- 18 – 24 years ☐
- 25 – 35 years ☐
- 36 – 45 years ☐

46 – 54 years ☐

55 years and above ☐

Prefer not to answer. ☐

**4. What is your employment status?**

Employed ☐

Self-employed ☐

Unemployed ☐

Studying ☐

**5. What is your race?**

Black ☐

White ☐

Asian ☐

Coloured ☐

Other ☐

**6. What is your primary means of transportation?**

Passenger Car (as a driver) ☐

Passenger Car (as a passenger) ☐

Bus ☐

Special purpose vehicles (ambulance, fire brigade, and police vehicle) ☐

Rideshare (Uber, Bolt in driver) ☐

Commercial Taxis or Combi ☐

Other (please specify) ………………………………… ☐

**7. Which type of public transport do you use most or prefer to use?**

Taxis or Combis ☐

Public transport bus service ☐

Transit buses ☐

Rideshare (Uber, Bolt in driver) ☐

Buses ☐

Not applicable ☐

## SECTION B: TRAFFIC CONDITION SURVEY

| 8. | How do you see traffic congestion in East London CBD? | 1 Disagree | 2 Strongly disagree | 3 Neutral | 4 Agree | 5 Strongly agree |
|---|---|---|---|---|---|---|
| | Major problem | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Minor problem | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Rarely a problem | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Not a problem | ☐ | ☐ | ☐ | ☐ | ☐ |

| 9. | How often is this traffic congestion happening in a week in East London CBD, Oxford Street? | 1 Disagree | 2 Strongly disagree | 3 Neutral | 4 Agree | 5 Strongly agree |
|---|---|---|---|---|---|---|
| | 1-2 days per week | ☐ | ☐ | ☐ | ☐ | ☐ |
| | 3-4 days a week | ☐ | ☐ | ☐ | ☐ | ☐ |
| | 5-6 days a week | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Every day | ☐ | ☐ | ☐ | ☐ | ☐ |

| 10. | What is your opinion regarding the usual times traffic congestion occurs on weekdays? | 1 Disagree | 2 Strongly disagree | 3 Neutral | 4 Agree | 5 Strongly agree |
|---|---|---|---|---|---|---|
| | 6:00 am – 10:00 am | ☐ | ☐ | ☐ | ☐ | ☐ |
| | 10:00 am – 2:00 pm | ☐ | ☐ | ☐ | ☐ | ☐ |
| | 2:00 pm – 6:00 pm | ☐ | ☐ | ☐ | ☐ | ☐ |
| | 6:00 pm – 10:00 pm | ☐ | ☐ | ☐ | ☐ | ☐ |
| | 10:00 pm – onwards | ☐ | ☐ | ☐ | ☐ | ☐ |

| 11. | What is your opinion regarding factors affecting commuters due to traffic congestion? | 1 Disagree | 2 Strongly disagree | 3 Neutral | 4 Agree | 5 Strongly agree |
|---|---|---|---|---|---|---|
| | Poor work performance | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Poor work productivity | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Late arrivals at home and work | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Car accidents | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Air pollution | ☐ | ☐ | ☐ | ☐ | ☐ |

| 12. | What is your opinion regarding the vehicle type contribution to congestion in EL-CBD Oxford Street? | 1 Agree | 2 Strongly agree | 3 Neutral | 4 Agree | 5 Strongly agree |
|---|---|---|---|---|---|---|
| | Passenger vehicles (cars, buses, and taxis) | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Commercial vehicles (trucks, tempos, and containers) | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Special purpose vehicles (ambulance, fire brigade, and police vehicle) | ☐ | ☐ | ☐ | ☐ | ☐ |

| 13. | What is your level of satisfaction during traffic congestion? | 1 Agree | 2 Strongly disagree | 3 Neutral | 4 Agree | 5 Strongly agree |
|---|---|---|---|---|---|---|
| | Friendly | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Frustration | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Aggression | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Tiredness and anger | ☐ | ☐ | ☐ | ☐ | ☐ |

| 14. | What is your opinion regarding driver behaviour contributing to congestion? | 1 Disagree | 2 Strongly disagree | 3 Neutral | 4 Agree | 5 Strongly agree |
|---|---|---|---|---|---|---|
| | Drivers do not stop at stop signs. | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Drivers do not obey traffic signs. | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Drivers seem to be going too fast. | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Drivers seem to be going too slow. | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Drivers do not yield to pedestrians. | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Drivers do not obey traffic signals. | ☐ | ☐ | ☐ | ☐ | ☐ |

| 15. | What is your opinion regarding the following factors contributing to congestion on Oxford Street? | 1 Agree | 2 Strongly agree | 3 Neutral | 4 Agree | 5 Strongly agree |
|---|---|---|---|---|---|---|
| | Limited parking space | ☐ | ☐ | ☐ | ☐ | ☐ |
| | High traffic volume | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Poor road infrastructure | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Reckless driving | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Car accidents | ☐ | ☐ | ☐ | ☐ | ☐ |
| | A large number of pedestrian crossings | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Road construction projects | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Ongoing maintenance projects | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Illegal loading & unloading of passengers | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Inadequate lane width | ☐ | ☐ | ☐ | ☐ | ☐ |
| | On-street parking | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Off-street parking | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Improper signal time plan | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Insufficient signal time design | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Poor driving conditions | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Disregarding traffic rules | ☐ | ☐ | ☐ | ☐ | ☐ |
| | The presence of taxi ranks in the CBD. | ☐ | ☐ | ☐ | ☐ | ☐ |

| **16.** | **What measures can be taken to reduce traffic congestion?** | **1 Agree** | **2 Strongly agree** | **3 Neutral** | **4 Agree** | **5 Strongly agree** |
|---|---|---|---|---|---|---|
| | More efficient public transport | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Adequate Traffic lights timed to control traffic. | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Carpooling | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Improve road infrastructure/Shoulders, /Lane widening. | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Parking management | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Flexible work hours/Work from home | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Introducing the local bus service | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Traveler information system | ☐ | ☐ | ☐ | ☐ | ☐ |

# APPENDIX B: ETHICAL CLEARANCE

Central University of Technology, Free State

**FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY**

**TECHNOLOGY**

**Department of Civil Engineering**

## APPLICATION FOR ETHICAL CLEARANCE TO CONDUCT RESEARCH IN THE FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

The Central University of Technology (CUT) Research Ethics and Integrity Policy applies to all undergraduate and postgraduate students and staff members who conduct research on CUT campuses and outside the campus. CUT policy requires any person who wishes to conduct research with CUT students and/or staff but is not affiliated with CUT to abide by the ethics framework. All CUT members who conduct research take responsibility for implementing this Policy.

### 1. APPLICANT INFORMATION

| | | | |
|---|---|---|---|
| **1.1.** | **Title (Prof Dr /Mr /Mrs /Ms)** | Mr | |
| **1.2** | **Name(s) and Surname** | Sikelela Magingxa | |
| **1.3** | **Student / Staff number** | 217012734 | |
| **1.4** | **Department** | Department of Civil Engineering | |
| **1.5** | **Campus** | Bloemfontein Campus | |
| **1.6** | **Postal address** | Mcobololo, PO Box 350, Engcobo, 5050 | |
| **1.7** | **Contact details** | Office | |
| | | Cell | 061 307 7282 |
| | | e-mail | sikmrwetyana@gmail.com |
| **1.8** | **Supervisor (s)/Project Leader** | Dr S Abejide, Mrs. Z Smith, and Prof. E Theron | |

| | | | |
|---|---|---|---|
| 1.9 | **Qualification registered for/Level of research** | ***Please tick the relevant option:*** | |
| | | Master's qualification | ✓ |
| | | Doctorate | |
| | | Independent research<br>(Non-qualification purposes) | |

| | | |
|---|---|---|
| 1.10 | **FRIC Approval Number (LS262a) (where applicable)** | Ref: FRIC xxx/xx |
| 1.11 | **Conflict of interest (Please underline/highlight):**<br><br>1) Personal relationship Yes/No | |
| | 2) Financial benefit Yes/No | |
| | ***If yes, please provide details:*** | |

**2. DETAILS OF THE STUDY**

| | |
|---|---|
| **2.1** | **Approved/Proposed title of the study/project /dissertation/thesis** |
| Capacity analysis and optimisation of traffic flow at three major intersections within the East<br>London central business district using quantum flow theory: A case study of Oxford Street | |
| **2.2** | **Research question(s)** |
| ✓ Are there critical causes of traffic congestion resulting in high traffic volume and low traffic flow?<br>✓ Is there an adverse impact of traffic congestion on society socially, economically, and emotionally? | |
| **2.3** | **Aim and objectives of the study** |

Aim: Using quantum flow theory at three major intersections, capacity analysis and optimisation of traffic flow to enhance safe mobility along the East London CBD, Oxford Street. Objectives:

- To identify causes of congestion and delays using quantum flow theory along the Oxford Street major intersections, analyse the data, and further use the data to provide an optimised route assignment network design that enhances safe mobility and efficiency using quantum flow theory.
- To develop a proposed Integrated Transportation Plan (ITP) using the quantum flow traffic method based on the data collected along Oxford Street to enhance clever city design using alternative charter preferences.

| | |
|---|---|
| **2.4** | **Research Methodology** |
| **2.4.1** | **Research participants and their age brackets (where applicable, e.g.**<br>**10 Students from the Civil Engineering Department)** |

For the questionnaire, research participants will be approximately 384 selected in the East London CBD, with different age groups.

| | |
|---|---|
| **2.4.2** | **How will participants be selected/sampled?** |

A simple random sampling method will be used to select the participants.

| | |
|---|---|
| **2.4.3** | **Research site(s) (e.g., Borong Construction**<br>**Site) Please list** |

East London (CBD), at 3 major intersections of Oxford Street, such as Caxton Street, Union Street, and North Street.

| | |
|---|---|
| **2.4.4** | **Data collection instruments (e.g., questionnaire(s)/interview schedule(s)/observation schedule(s)/artefacts/other)** |

***List all instruments to be used and attach copies/a copy/copies/ schedule***

- ***For each data collection instrument, explain the quality measures to be observed***
- ***Please attach a copy of all data collection instruments for the study (where applicable).*** Data Collection Instruments:

| | |
|---|---|
| | • Questionnaire (attached) |
| **2.4.5** | **Data collection procedure (Please outline WHEN, WHERE, and HOW data will be collected)** |
| | For the purpose of this study, a questionnaire was used. The questionnaires will use a closed-ended five-point Likert scale, ranging from 1=Strongly Disagree to Agree 5=Strongly. Respondents will have the option of ticking or ranking the most relevant response(s). The surveys will be handed to commuters and drivers as respondents along Oxford Street by the researchers using a simple random selection procedure. The surveys will be distributed by the researchers to 384 respondents as calculated. If necessary, the researchers will read and clarify the questions to respondents with low literacy levels who cannot read and understand essential responses. |

## 3. Proposed study of the plan

| | | |
|---|---|---|
| | **Set out your intended plan of work for the research, indicating important target dates necessary to meet your proposed deadlines.** | |
| | **Activity**<br>Proposal submission<br>Literature review<br>Research Methodology<br>Data collection<br>Data analysis and interpretation of results<br>Discussion of results, findings, and conclusions<br>Dissertation writing, Advisor review, and editing. | **Date**<br>March 2022 – July 2022 (complete)<br>August 2022 – November 2022 (complete)<br>December 2022 - February 2023 (complete)<br>May 2023 – June 2023<br>July 2023 – August 2023<br>September 2023 – October 2023<br>November 2023 |
| | Final Dissertation submission | December 2023 |

**4. ETHICAL ISSUES AND RISK ASSESSMENT**

To assess whether your proposed research is ethically compliant, ethics risks are categorised into four categories:

(1) Research involving minor risk

The likelihood of projected harm or inconvenience in the research is not greater than that experienced daily.

(2) Research involving low risk

Research in which the only anticipated risk is potential awkwardness or discomfort to the participants.

(3) Research involving medium risk

Research in which there is a possible risk of harm or discomfort, but where appropriate steps can be taken to lessen or moderate the overall risk.

(4) Research involving high risk

Research in which there is a real and foreseeable risk of harm and discomfort may lead to a serious adverse event if not managed responsibly.

| | | | | |
|---|---|---|---|---|
| **4.1** | **Will human research participants be used in your study?**<br>*Please mark with an X or ✓ in the Yes/No/N/A box* | ✓ **Yes** | **No** | **N/A** |
| **4.2** | **If yes, does the research study involve any of the following:** | | | |
| a) Children or youth under the age of 18<br>(Attach parental consent letter) | | | ✓ | |
| b) Individuals living with disabilities (physical, mental and/or sensory)<br>(Attach consent letter of legal guardian) | | | ✓ | |
| c) Individuals who might find it difficult to make independent and informed decisions for socio-economic, cultural, political and/or medical reasons | | | ✓ | |

| | | | |
|---|---|---|---|
| d) Communities that might be considered vulnerable, thus finding it difficult to make independent and informed decisions for socio-economic, cultural, political and/or medical reasons | | ✓ | |
| e) Individuals who might be vulnerable for age-related reasons, e.g., the elderly | | ✓ | |
| f) Individuals whose spoken language differs from the language used for the research<br><br>(Make sure you translate your consent form and participant information sheet in the participants' first language – you should also have an interpreter if you do interviews – describe it below the table) | | ✓ | |
| g) Women considered to be vulnerable (pregnancy, victimisation, marginalised, etc.) | | ✓ | |
| h) Other (Please explain): | | | |

| **4.3** | **Will data collection involve any of the following?** | **Yes** | **No** | **N/A** |
|---|---|---|---|---|
| | a) Access to confidential data without prior permission of participants | | ✓ | |
| | b) Participants expected to commit an act which might reduce self-respect or cause them to experience shame, embarrassment, or regret | | ✓ | |
| | c) Expose participants to worrying or upsetting questions or to processes which may have disagreeable or harmful side effects | | ✓ | |
| | d) The use of stimuli, errands or procedures which may be experienced as stressful, harmful, or hostile | | ✓ | |

| | | | |
|---|---|---|---|
| e) Any use of materials that are risky to human beings | | ✓ | |

**4.4 If you answered "Yes" to any previously mentioned questions, explain (attach as an appendix) and justify. Explain the steps you will take to minimise the potential stress/harm. *(Please indicate if it does not apply to your study.)***

**4.5 Confidentiality of participants' identity**

| | | | | |
|---|---|---|---|---|
| **4.5.1** | **Will the identity and privacy of participants be protected through pseudonyms or other forms of identification and the use of an informed consent form, which specifies (in a language that participants will understand):** | **✓ YES** | **NO** | **N/A** |
| | *Place an 'X or ✓ in the Yes/No box*. | | | |
| **4.5.2** | **Please note that participants should be informed about the following (where applicable)** | | | |
| a) The purpose/s of the research and how it is conducted | | ✓ | | |
| b) The researcher, project leader and supervisor's identity, their institutional association and their contact details | | ✓ | | |
| c) Voluntary participation of participants | | ✓ | | |
| d) Making sure that participants' responses will be treated in a confidential manner | | ✓ | | |
| e) Be transparent about any possible limits on confidentiality which may apply | | ✓ | | |

| | | | |
|---|---|---|---|
| f) Ensuring participants that they are free to withdraw from the research at any time without any harmful or undesirable consequences to themselves | ✓ | | |
| g) How the findings of the study will have any benefits, or may receive as a result of their participation in the research | ✓ | | |
| ***4.5.2 Please attach the proposed consent and assent documents prepared to address all the above, if a full explanation is needed explaining how participants will be respected and protected.*** | | | |

**5. DOCUMENTS TO BE ATTACHED TO THE APPLICATION**

| ***The following documents must be attached as a prerequisite for approval to undertake research.*** ***In the Department (where applicable)*** | |
|---|---|
| **5.1** | LS 262a approved by the FRIC (FEBIT) |
| **5.2** | Proof of registration/Funding received and funder reference details |
| **5.3** | Data collection instruments as identified under 2.4.4 |

**6. DECLARATION BY THE APPLICANT**

I undertake to use the information I acquire through my research in a balanced and responsible manner. I furthermore take note of, and agree to adhere to the following conditions (where applicable):

a) I will schedule my research activities in consultation with the relevant Company or Organisation and research participants (where relevant);
b) I agree that the involvement of participants in my research is voluntary, and that participants have a right to decline to participate;
c) I will obtain signed consent forms from participants before any engagement with them;
d) I will inform participants about the use of recording devices such as tape-recorders and cameras, and participants will be free to reject them if they wish;
e) I will always honour participants' right to privacy, anonymity, confidentiality and respect for human dignity. Participants will not be identifiable in any way from the results of my research, unless written consent is obtained otherwise.
f) All interviews (recordings) will be transcribed verbatim and analysed as per conventional data analysis techniques (example(s) of interview transcript to be included in final dissertation)
g) I will adhere to the principles of rigorous data collection, analysis and interpretation consistent with the design of the study;
h) I will keep a data trail for possible auditing purposes as well as the safekeeping of raw data for a period of three years after publication of the results;
i) I will send the draft research findings to research participants before finalisation, to validate the accuracy of the information in the report;
j) I will not use the resources of the university when I am conducting my research (such as stationery, photocopies, faxes, and telephones) and
k) I will include a disclaimer in any report, publication or presentation arising from my research, that the findings and recommendations of the study do not represent the views of the Central University of Technology.
l) Aside from laboratory as well as consumables or materials supplied by the university needed to complete practical projects, which might be central to my study (dependent on study field), I will not use the resources of the University when I am conducting my research (such as stationery, photocopies, faxes, and telephones).
m) All practical artefacts produced in support of my study using the university's laboratories, consumables, and materials will remain the property of the University.
n) If I supply my materials and consumables, I will permit access to all practical projects or artefacts to the University for three (3) years for exhibition purposes.
o) All data collected for the research (including, but not limited to, completed questionnaires; statistical analysis performed on the data; interview audio files/transcripts; artefacts/audio-visual materials; documents) will be kept safe at a designated space at the university for a period of at least three years. Computer files will be backed up and password-protected.

I declare that all statements made in this application are true and accurate. I accept the conditions associated with the granting of approval to conduct research and undertake to abide by them.

| | |
|---|---|
| **STUDENT SIGNATURE / PROJECT LEADER SIGNATURE / SIGNATURE OF RESEARCHER** | [signature] |
| **DATE** | 12/04/2023 |

**7. DECLARATION BY SUPERVISOR(S) (where applicable)**

| | |
|---|---|
| I/We declare that I/we shall oversee the student's adherence to all statements as set out above. | |
| SIGNATURE (Main supervisor) | |
| SIGNATURE (Co-supervisor) | Smith<br>**Mrs Zandri Smith** |
| **DATE** | 12/04/2023 |

**FOR OFFICIAL USE APPROVAL OF FEBIT ETHICAL COMMITTEE (FRIC)**

| | | | |
|---|---|---|---|
| ***Please tick the relevant decision and provide conditions/reasons where applicable*** | | | |
| **Decision** | | | ***Please tick the relevant option.*** |
| 1. | Application approved | | |
| 2. | Ethical clearance number | FRIC: | |
| 3. | Application approved subject to certain conditions. ***Specify conditions below*** | | |
| | | | |
| 4. | Application not approved***. Provide reasons for non-approval below.*** | | |
| | | | |
| **SIGNATURE: Chairperson: Ethics Committee** | | | |
| **DATE** | | | |

Cc Dean: FEBIT

# APPENDIX C: RESEARCH STUDY INFORMATION LEAFLET AND CONSENT FORM

**FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY**

**Department of Built Environment**

## RESEARCH STUDY INFORMATION LEAFLET AND CONSENT FORM

**DATE**

*27/03/2023*

**TITLE OF THE RESEARCH PROJECT**

*Capacity analysis and optimisation of traffic flow at three major intersections within the East London central business district using quantum flow theory: A case study of Oxford Street.*

**PRINCIPLE INVESTIGATOR / RESEARCHER(S) NAME(S) AND CONTACT NUMBER(S):**

*Name: Sikelela Magingxa Student No: 217012734 Contact No: 0613077282*

**FACULTY AND DEPARTMENT:**

*Faculty of Engineering, Built Environment and Information Technology*

*Department of Civil Engineering*

**STUDYLEADER(S) NAME AND CONTACT NUMBER:**

| | | |
|---|---|---|
| *Dr S Abejide* | *sabejide@wsu.ac.za* | *0789289759* |
| *Mrs. Z Smith* | *zventer@cut.ac.za* | *0832636085* |
| *Prof E Theron* | *etheron@cut.ac.za* | *051 507 3646* |

**WHAT IS THE AIM / PURPOSE OF THE STUDY?**

Using quantum flow theory at three major intersections, the aim is to analyse the capacity and optimise the traffic flow to enhance safe mobility along the East London CBD, Oxford Street.

**WHO IS DOING THE RESEARCH?**

This research is being conducted by Sikelela Magingxa (student number: 217012734). I am a Civil Engineering Student at the Central University of Technology, Free State, studying for a Master of Engineering in Civil Engineering.

**HAS THE STUDY RECEIVED ETHICAL APPROVAL?**

This study has received approval from the Faculty Research and Innovation Committee (FRIC) of the CUT. A copy of the approval letter can be obtained from the researcher.

**Approval number:** Click here to enter text.

**WHY ARE YOU INVITED TO TAKE PART IN THIS RESEARCH PROJECT?**

This study has been forwarded to you on behalf of Sikelela Magingxa, as you have been identified as a suitable participant in my research. You have been selected as a participant in this study as a vehicle owner and/or a resident of East London. As someone who uses East London and Oxford Street frequently, you are fully aware of the daily challenges of traffic congestion. You are therefore in a good position to know the traffic flow scenarios you come across during your travels and have an opportunity to contribute to the measures to mitigate the traffic congestion phenomenon.

**WHAT IS THE NATURE OF PARTICIPATION IN THIS STUDY?**

Your part in this study will be in the form of a questionnaire. Questions will be asked to get an overview of your travel experience, especially at peak hours. You will have to answer a series of questions, some asking for additional information if you wish to add. The questionnaire should take approximately 15 minutes and no longer than 30 minutes. There will be no information retrieved or published which has the potential to identify you. There are no right or wrong answers to these questions, so please answer honestly and freely.

**CAN THE PARTICIPANT WITHDRAW FROM THE STUDY?**

As a volunteer, you are welcome to end your participation at any time, and you do not need to provide any justification for this. If you decide to stop participation early, you will be asked if you are content for the data collected thus far to be retained and included in the study. However, if you prefer, any data collected can be destroyed and not included in the study. Once the research has been completed and the data analysed, it will not be possible to withdraw your data from the survey.

**WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?**

This study is meant to benefit society by improving the transportation sustainability of mid-sized cities. Traffic congestion has been hitting cities globally. This study tries to alleviate that by using East London CBD, Oxford Street, as a case study to analyse the capacity and optimise the traffic flow using quantum flow theory. The successful implementation of the study results will result in high traffic flow, fuel cost reduction, vehicle miles travelled and reduced travel times for commuters and drivers.

**WHAT IS THE ANTICIPATED INCONVENIENCE OF TAKING PART IN THIS STUDY?**

There are no physical risks. The interview may take some time to complete, but it will be limited to the time that you are available.

**WILL WHAT I SAY BE KEPT CONFIDENTIAL?**

Yes, the raw data will only identify you by number and will be completely confidential. The raw data will be kept securely on a password-protected research folder and retained for at least 10 years. The raw data will be disposed of securely when no longer required. The anonymous data, which does not identify you, will be publicly shared at the end of the project and made available for open access.

**HOW WILL THE INFORMATION BE STORED AND ULTIMATELY DESTROYED?**

The researcher will safely store the completed questionnaires for future research or academic purposes. Electronic information will be stored on a password-protected computer, external hard drive, and cloud service (all password protected). Future use of the stored data will be subject to further FRIC approval if applicable. Information will be destroyed by shredding hard copies, deletion of all electronic data, and checked by a data storage expert for recovery. No risks are anticipated in terms of data gained from the questionnaires.

**WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?**

No payment or reward is offered for participation in this study.

**HOW WILL THE PARTICIPANT BE INFORMED OF THE FINDINGS / RESULTS OF THE STUDY?**

If you want to be informed of the final research findings, please contact Sikelela Magingxa at 061 307 7282 or sikelelamagingxa@gmail.com. The findings will be accessible after the results have been recorded. The completed journal article and other published material will be available electronically through the university, academic journals, and public research platforms. Should you require further information or want to contact the researcher about any aspect of this study, please get in touch with Sikelela Magingxa. Should you have concerns about how the research has been conducted, you may contact Mrs. Z. Smith (zventer@cut.ac.za), my co-supervisor who is a Lecturer at the Department of Civil Engineering, Central University of Technology, or Dr S. Abejide (sabejide@wsu.ac.za) my primary supervisor who is a Lecturer at the Department of Civil Engineering at Walter Sisulu University.

**THANK YOU FOR TAKING THE TIME TO READ THIS INFORMATION SHEET AND FOR PARTICIPATING IN THIS STUDY.**

CONSENT TO PARTICIPATE IN THE STUDY (2023) *capacity analysis and Using quantum flow theory, optimise traffic flow in the three major intersections of East London, Oxford Street.*

I, ______________________________________ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits, and anticipated inconvenience of participation.

I have read (or explained to me) and understood the study described in the information sheet. I have had an opportunity to ask questions and am prepared to participate in the study. I know my participation is voluntary, and I can withdraw without penalty. I am aware that the findings of this study will be processed into a research report, journal publications, and/or conference proceedings. I am fluent in English and understand these documents, or have had the information explained to me in a language I know well.

Indicate clearly by marking either Yes or No with an 'X'

| | | |
|---|---|---|
| I agree to participate in the questionnaire | YES | NO |
| I agree that the information obtained from the questionnaire may be referenced. | YES | NO |
| I wish to remain anonymous as far as possible | YES | NO |
| I have received a signed copy of the informed consent agreement. | YES | NO |

Full Name of Participant: ___________________________________________________________

Signature of Participant: __________________________________ Date: ____________________

Full Name(s) of Researcher(s):

___________________________________________________________

Signature of Researcher: __________________________________ Date: ____________________

Full Name(s) of Researcher(s) conducting the interview:

___________________________________________________________

Signature of Researcher conducting the interview:

____________________________________ Date: ____________________

### Table 4. 5: Indication of the duration respondents have lived in EL

| Duration of residence in EL | Percentage |
|---|---|
| I don't live in East London | 3.1% |
| Less than 1 year | 19.0% |
| 1-3 years | 25.8% |
| 3-6 years | 16.9% |
| 6-10 years | 20.6% |
| More than 10 years | 14.6% |

### Table 4. 6: Gender

| Gender | Percentage |
|---|---|
| Male | 43.2% |
| Female | 51.6% |
| Other | 2.1% |
| Prefer not to answer | 3.1% |

### Table 4. 7: Age group

| Age | Percentage |
|---|---|
| Under 18 years | 3.1% |
| 18-24 years | 27.6% |
| 25-35 years | 32.8% |
| 36-45 years | 19.5% |
| 46-54 years | 10.4% |
| 55 years and above | 6.5% |
| Prefer not to answer | 0.0% |

**Table 4. 8: Occupation Status**

| Occupation status | Percentage |
|---|---|
| Employed | 46.6% |
| Self employed | 21.4% |
| Unemployed | 12.5% |
| Studying | 19.5% |

**Table 4. 9: The primary means of transport**

| Transportation means | Percentage |
|---|---|
| Passenger car (as a driver) | 27.3% |
| Passenger car (as a passenger) | 25.3% |
| Bus | 12.2% |
| Special-purpose vehicles | 4.4% |
| Rideshare | 18.0% |
| Commercial Taxis or Combi | 12.8% |
| Other | 0.0% |

**Table 4. 10: The type of public transport preferred the most**

| Public transport preference | Percentage |
|---|---|
| Taxis or Combis | 37.2% |
| Public transport bus service | 6.0% |
| Transit buses | 2.3% |
| Rideshare | 34.1% |
| Buses | 6.5% |
| Not applicable | 13.8% |

**Table 4. 11: The observation of respondents on traffic congestion**

| | Disagree & strongly disagree. | Neutral | Agree & strongly agree |
|---|---|---|---|
| Major problem | 5.7% | 2.1% | 92.2% |
| Minor problem | 87.8% | 6.3% | 6.0% |
| Rarely a problem | 76.3% | 19.5% | 4.2% |
| Not a problem | 88.3% | 6.3% | 5.5% |

**Table 4. 12: Vehicle type contribution to traffic congestion**

| Type of vehicle contributing to traffic congestion | Disagree & strongly disagree | Neutral | Agree & strongly agree |
|---|---|---|---|
| Passenger vehicles | 9.6% | 3.6% | 86.7% |
| Commercial vehicles | 44.8% | 28.9% | 26.3% |
| Special-purpose vehicles | 68.5% | 20.3% | 11.2% |

**Table 4. 13: Factors affecting residents as a result of congestion**

| Impact of traffic congestion | Disagree & strongly disagree | Neutral | Agree & strongly agree |
|---|---|---|---|
| Poor work performance | 14.1% | 16.1% | 69.8% |
| Poor productivity | 13.8% | 14.1% | 72.1% |
| Late arrivals at home & work | 6.0% | 3.9% | 90.1% |
| Car accidents | 70.3% | 11.5% | 18.2% |
| Air pollution | 23.4% | 45.6% | 31.0% |

### Table 4. 14: The level of satisfaction during traffic congestion

| Satisfactory level during a traffic jam | Disagree & strongly disagree | Neutral | Agree & strongly agree |
|---|---|---|---|
| Friendly | 77.6% | 15.4% | 7.0% |
| Frustration | 3.9% | 11.5% | 84.6% |
| Aggression | 14.3% | 24.0% | 61.7% |
| Tiredness & anger | 5.5% | 10.4% | 84.1% |

### Table 4. 15: Traffic congestion on weekdays

| Traffic congestion on weekdays | Disagree & strongly disagree | Neutral | Agree & strongly agree |
|---|---|---|---|
| 1-2 days per week | 85.4% | 6.8% | 7.8% |
| 3-4 days per week | 35.4% | 15.6% | 49.0% |
| 5-6 days per week | 10.4% | 8.1% | 81.5% |
| Everyday | 70.3% | 16.9% | 12.8% |

### Table 4. 16: Peak hours of traffic congestion

| Peak hours of traffic congestion | Disagree & strongly disagree | Neutral | Agree & strongly agree |
|---|---|---|---|
| 6:00 am - 10:00 am | 4.4% | 5.5% | 90.1% |
| 10:00 am - 2:00 pm | 33.6% | 43.5% | 22.9% |
| 2:00 pm - 6:00 pm | 13.0% | 7.6% | 79.4% |
| 6:00 pm - 10:00 pm | 49.2% | 16.1% | 34.6% |
| 10:00 pm - onwards | 72.4% | 16.1% | 11.5% |

### Table 4. 17: The behaviour of drivers

| The behaviour of drivers | Disagree & strongly disagree | Neutral | Agree & strongly agree |
|---|---|---|---|
| Drivers do not stop at stop signs | 18.0% | 8.3% | 73.7% |
| Drivers do not obey traffic signs | 14.8% | 7.3% | 77.9% |
| Drivers seem to be going too fast | 54.9% | 16.9% | 28.1% |
| Drivers seem to be going too slow | 59.4% | 16.4% | 24.2% |
| Drivers do not yield to pedestrians | 16.7% | 12.2% | 71.1% |
| Drivers do not obey traffic signals | 13.0% | 10.7% | 76.3% |

### Table 4. 18: Factors contributing to traffic congestion (1)

| Traffic congestion factors | Disagree & strongly disagree | Neutral | Agree & strongly agree |
|---|---|---|---|
| Limited parking space | 14.6% | 10.7% | 74.7% |
| High traffic volume | 6.3% | 1.3% | 92.4% |
| Poor road infrastructure | 59.1% | 12.0% | 28.9% |
| Reckless driving | 11.5% | 14.6% | 74.0% |
| Car accidents | 32.0% | 35.7% | 32.3% |
| A large number of pedestrians are crossing | 23.4% | 18.2% | 58.3% |

**Table 4. 19: Factors contributing to traffic congestion (2)**

| Traffic congestion factors | Disagree & strongly disagree | Neutral | Agree & strongly agree |
|---|---|---|---|
| Road construction projects | 58.3% | 13.8% | 27.9% |
| Ongoing maintenance projects | 51.0% | 16.7% | 32.3% |
| Illegal loading & unloading of passengers | 20.1% | 7.8% | 72.1% |
| Inadequate lane width | 32.6% | 37.5% | 29.9% |
| On-street parking | 15.9% | 19.5% | 64.6% |
| Off-street parking | 59.9% | 14.6% | 25.5% |

**Table 4. 20: Factors contributing to traffic congestion (3)**

| Traffic congestion factors | Disagree & strongly disagree | Neutral | Agree & strongly agree |
|---|---|---|---|
| Improper signal time plan | 21.6% | 22.9% | 55.5% |
| Insufficient signal time design | 23.2% | 24.5% | 52.3% |
| Poor driving conditions | 49.2% | 11.2% | 39.6% |
| Disregarding traffic rules | 18.0% | 14.3% | 67.7% |
| The presence of taxi ranks in the CBD | 32.6% | 12.5% | 54.9% |

**Table 4. 21: Measures to be taken to alleviate traffic congestion**

| Traffic congestion measures | Disagree & Strongly disagree | Neutral | Agree & strongly agree |
|---|---|---|---|
| More efficient public transport | 12.0% | 9.1% | 78.9% |
| Adequate traffic lights are timed to control traffic | 16.1% | 9.4% | 74.5% |
| Carpooling | 9.1% | 6.8% | 84.1% |
| Improve road infrastructure/shoulder/lane widening | 44.5% | 17.2% | 38.3% |
| Parking management | 21.6% | 15.4% | 63.0% |
| Flexible work hours/ work from home | 39.1% | 27.6% | 33.3% |
| Introducing the local bus service | 20.8% | 12.2% | 66.9% |
| Traveller information system | 26.3% | 27.6% | 46.1% |