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Graduate School of Business and Leadership

Investigating the Potential Impact of Autonomous Vehicles, A KwaZulu-Natal Civil Engineer's Perspective.

By

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“Don’t you worry, child, see heavens got a plan for you.”

- SWEDISH HOUSE MAFIA

ABSTRACT

This dissertation paper examines the potential impact of autonomous vehicles from the perspective of fifteen civil engineers based in KwaZulu-Natal. With the advent of this groundbreaking autonomous vehicle technology, it is crucial to assess its implications on various aspects of transportation systems and infrastructure development. The study examines the potential benefits and challenges of adopting autonomous vehicles, including their impact on traffic congestion, road safety, and environmental sustainability. Autonomous vehicles are still in the research and development phase, but several influential stakeholders are already establishing partnerships to strengthen their position in future transportation markets. The invention of automobiles has shaped our society, influencing how we commute, where we live, and how we build our cities and infrastructure. While automotive vehicles offer transportation freedom and contribute to economic growth, they also pose sustainability challenges. Issues like safety, environmental impact, traffic congestion, and time spent on operation highlight the need for more sustainable transportation solutions. Autonomous vehicles can sense their environments to perform at least some aspects of safety-critical control (like steering, throttling, or braking) without direct human input. This dissertation aims to develop a strong foundation for anticipating the potential impacts of vehicle automation advancements in South Africa. User acceptance of autonomous vehicles is a crucial concern in the transportation industry. It's vital not to underestimate their potential impact and implications. These vehicles have the capacity to make a significant positive global impact, making them valuable assets for governments and automotive industries alike. The study will utilize a qualitative research approach involving a sample of fifteen (15) civil engineers employed in the road infrastructure sector within the KwaZulu-Natal region. This research will provide valuable insights and recommendations for policymakers, engineers, and stakeholders involved in the future integration of autonomous vehicles in KwaZulu-Natal and beyond through a comprehensive review of existing literature and expert interviews. The study suggests future research should compare regions in South Africa, use quantitative methods, track long-term impacts, collaborate across disciplines, study public perceptions, examine legal frameworks, assess environmental impacts, monitor technological advancements, analyze economic implications, and engage local communities. The study concludes that autonomous vehicles offer significant potential for revolutionizing transportation in South Africa. They promise improved efficiency, enhanced safety features, and various societal impacts, including changes in urban planning and job creation. Despite initial costs, long-term benefits such as reduced accidents and increased efficiency outweigh them.

Keywords: "Autonomous driving, "Autonomous Vehicles", "Self-driving car," and "Driverless car."

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF GRAPHS

List of Acronyms

ADAS	Advanced Driver Assistance Systems
AI	Artificial Intelligence
AV	Autonomous Vehicle
AVT	Autonomous Vehicle Technology
CAV	Connected and Autonomous Vehicle
COVID-19	Novel Coronavirus
DOTKZN	Department of Transport KwaZulu-Natal
DSRC	Dedicated Short-Range Communications
ECU	Electronic Control Unit
GNSS	Global Navigation Satellite System
GPS	Global Positioning Systems
HD Map	High-Definition Map
ITS	Intelligent Transportation Systems
KZN	KwaZulu-Natal
LiDAR	Light Detection and Ranging
ML	Machine Learning
NHTSA	National Highway Traffic Safety Administration
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
PPE	Perception, Planning, and Execution
RADAR	Radio Detection and Ranging
SAE	The Society of Automotive Engineers
SANRAL	The South African National Roads Agency Limited

CHAPTER ONE: INTRODUCTION

1.1. BACKGROUND AND STUDY CONTEXT

Autonomous vehicles, or self-driving cars, have the remarkable capability to perceive their surroundings and execute essential safety-related functions like steering, acceleration, and braking without the need for human intervention. In recent years, there has been a significant surge in the development of autonomous vehicles as technological barriers that hindered their introduction have steadily diminished. However, beyond these technical obstacles exist additional challenges, notably user acceptance, which must be addressed to ensure the successful integration of autonomous vehicles into the market. The primary objective of this thesis is to establish a comprehensive framework that anticipates the potential impacts arising from advancements in vehicle automation, specifically in the context of South Africa.

1.2. PROBLEM STATEMENT OF THE STUDY

Autonomous vehicles continue to advance in technology rapidly and become closer to widespread implementation. It is crucial to understand how autonomous vehicles will affect various facets of infrastructure, transportation systems, and urban development.

The prospects and challenges of implementing autonomous vehicles in KwaZulu-Natal have gained significant attention in recent years. According to Mtshali and Jili (2022), autonomous vehicles promise to transform transportation systems by enhancing safety, reducing traffic congestion, and improving fuel efficiency. The introduction of autonomous vehicles in KwaZulu-Natal holds the promise of a substantial decrease in road accidents and fatalities. These vehicles are equipped with cutting-edge sensors and artificial intelligence algorithms that exhibit an enhanced capacity to identify and react to potential hazards, surpassing the capabilities of human drivers (Mtshali and Jili, 2022). In addition to enhancing safety, autonomous vehicles hold the potential to alleviate traffic congestion by efficiently managing traffic flow and reducing the overall volume of vehicles on the road. This can be achieved through innovative practices like ride-sharing and platooning. This paradigm shift can potentially deliver significant advantages, translating into substantial time and cost savings for commuters in the KwaZulu-Natal region.

Various challenges concerning autonomous vehicles must be tackled before fully integrating into the transportation system. These challenges encompass establishing comprehensive regulatory frameworks, meeting the necessary infrastructure prerequisites, acquiring public acceptance, and addressing pressing cybersecurity concerns (Mtshali and Jili, 2022).

1.3. MOTIVATION OF THE STUDY

The rapid progress of autonomous vehicle technology carries profound and far-reaching implications for various fields, such as transportation, infrastructure, and urban development (Bohm and Häger, 2015). Civil Engineers hold a crucial position among the stakeholders tasked with comprehending the potential consequences of this technology. The accelerating pace at which autonomous vehicles advance is of utmost importance to thoroughly examine and evaluate their specific impact on civil engineering. Civil engineers have the capability to foresee proactively, adjust to, and tackle the challenges and possibilities posed by this groundbreaking technology (Pakzadnia et al., 2022).

The province of KwaZulu-Natal in South Africa offers a unique context to examine the potential implications of autonomous vehicles. Conducting a comprehensive analysis of how this emerging technology will impact transportation systems, infrastructure planning, and urban development in KwaZulu-Natal is essential for making informed decisions and ensuring the region's resilience in future challenges (Pakzadnia et al., 2022). Through an examination of this context, valuable insights can be acquired, empowering policymakers and stakeholders to proactively formulate strategies and adjust to the profound transformations that autonomous vehicles are poised to introduce to KwaZulu-Nata.

Civil Engineers are central figures in infrastructure development, transportation planning, and urban design, making their expertise indispensable when understanding and evaluating the potential implications of autonomous vehicles (Zhao et al., 2021). These professionals possess the unique knowledge and skills required to assess the suitability of existing systems for accommodating autonomous vehicles and develop effective strategies for seamless integration.

The successful integration of autonomous vehicles requires proactive planning, policy framework development, and infrastructure modifications. The formulation of comprehensive policies is equally critical. These policies must encompass a wide range of considerations, including safety standards, liability frameworks, data privacy regulations, and traffic laws that account for the unique characteristics of autonomous vehicles. Developing a coherent and adaptable policy framework is paramount to ensuring a smooth transition (Zhao et al., 2021).

1.4. AIM AND OBJECTIVES OF STUDY

1.4.1. Aim of the Study

This study aims to delve into the potential ramifications of autonomous vehicles from the viewpoint of a civil engineer operating in the region of Kwazulu-Natal. This research seeks to comprehensively explore and analyse the various ways in which autonomous vehicles could influence transportation, infrastructure, safety, sustainability, and urban development within the context of Kwazulu-Natal. Approaching the study from a civil engineering perspective, the goal is to offer valuable insights and recommendations. These can serve as a roadmap for future planning, policymaking, and infrastructure development, facilitating the region's seamless and beneficial integration of autonomous vehicles.

1.4.2. Research Objectives of the Study

1. To investigate the efficiency of autonomous vehicles over traditional vehicles.
2. To investigate the safety aspect of drivers and vehicles from the advanced technologies of autonomous vehicles.
3. To investigate the impact on social issues faced by introducing autonomous vehicles within the South African transport infrastructure.
4. Explore the possible financial costs and benefits changes when applying autonomous vehicle technology for everyday use.
5. Investigate the challenges encountered by Autonomous vehicles.

1.4.3. Research Questions of the Study

The study will discuss the impacts of the technology in terms of the efficiency, safety aspects, social problems, and financial cost implications of introducing autonomous vehicles to the South African road network.

1. What is the efficiency of autonomous vehicles over traditional vehicles?
2. What is the safety aspect of drivers and vehicles from the advanced technologies of autonomous vehicles?
3. What is the impact on social issues faced by introducing autonomous vehicles within the South African transport infrastructure?
4. What are possible financial costs and benefits changes when applying autonomous vehicle technology for everyday use?
5. What are the challenges encountered by autonomous vehicles?

1.5. PRELIMINARY LITERATURE REVIEW

Autonomous vehicles are defined as vehicles with at least some safety control functions that occur without direct driver input (Zmud and Sener, 2017). Autonomous vehicles can also be defined as vehicles where at least some aspects of the safety use sensors, cameras, Light Detection And Ranging (LIDAR), Global Positioning Systems (GPS), and other on-board technologies to operate with a reduced to no human interaction (Zmud and Sener, 2017). Autonomous vehicles represent a field of Advanced Driver Assistance Systems (ADAS) whereby more driving responsibilities are transferred from a driver to a vehicle for convenience and safety (Zmud and Sener, 2017). Autonomous vehicles can be any vehicle, such as passenger vehicles, public transport, or freight vehicles. The “Google Car” is a prototype of autonomous vehicles (Zmud and Sener, 2017).

According to studies conducted by Leathrum et al. (2018), Autonomous vehicles provide numerous benefits over systems requiring human control. Driverless cars could be safer since the system does not suffer from a lack of attention. This has been supported by Chater et al. (2018), stating that autonomous vehicles, which promise significant gains in human welfare through improved mobility safety, bring to light fundamental challenges for cognitive science and artificial intelligence, not just in sensing and control.

An estimated 195,085 deaths were recorded on South African roads between 2008 and 2022 (RTMC, 2022). Most of these cases were a result of human error. A road traffic crash is a complex event that emerges from the intricate interplay of various elements within the system. This system encompasses the design and condition of the roads themselves, the surrounding environment, the vehicles' characteristics and conditions, and the road users' behavior and actions. It is within this dynamic interaction that road traffic accidents occur, and a comprehensive understanding of these factors is essential for effective accident prevention and safety measures (RTMC, 2017). Vehicle dynamics and stability have been of considerable interest to automotive engineers, automobile manufacturers, the government, public safety groups, and the general public for several years. The transportation system is fragile in Foshan (a City in China) due to the poor linking arrangement, insufficient public transport vehicles, and irrational car design. There is no guarantee of priority for public transport, and lowering service standards makes public transport less attractive to citizens (Annex, 2018). This can be compared to South Africa because it has a similar situation with the transportation infrastructure.

Traffic congestion accounted for 87 billion dollars in production costs in the United States alone in 2018 (INRIX, 2019). According to INRIX (2019), the average Bostonian driver lost 164 hours in the last year (2018) due to traffic congestion. Autonomous vehicles provide substantial benefits over conventional cars, such as improved traffic safety. This measure has the potential to mitigate the staggering toll of 42,000 annual fatalities attributed to traffic accidents in the United States (Chu et al., 2015), significantly better fuel economy (Rosenzweig and Bartl, 2015), and car sharing (Ross and Guhathakurta, 2017) are just a few of the many benefits that the introduction of self-driving cars brings to the table. Almost every major car manufacturer has started working on autonomous driving, and it is expected that it won’t take long for most manufacturers to bring their first self-driving cars to market.

Autonomous vehicles, a new technology introduced to an environment, create a significant issue for user acceptance as they cannot be taken for granted (Kaan, 2017). It could be said that self-driving vehicles have a positive global impact on society and, therefore, could be considered very valuable for both the government and the automotive industries (Kaan, 2017).

The potential implications for policy and planning by autonomous vehicles are extensive and varied, influencing issues such as parking provision and mobility for people with disabilities (Millard-Ball, 2018). The presence of autonomous vehicles on the road adds an extra dimension of difficulty to the uncertainties associated with their interactions with other road users. These interactions have significant implications for urban neighborhoods' physical layout and design, as they need to adapt to accommodate this emerging technology (Millard-Ball, 2018).

1.6. RESEARCH METHODOLOGY

The researcher adopted a qualitative approach to comprehend the effects of implementing autonomous vehicles on roads within KwaZulu-Natal. The researcher opted for semi-structured interviews to collect data, as this method comprehensively analyzes the research topic without restricting participant responses. The interviews were conducted with various Civil engineers in KwaZulu-Natal who have knowledge of road infrastructure; a purposeful sample size of fifteen (15) participants was used in the qualitative study.

The researcher-initiated contact with the respondents to arrange interview meetings. The selection of interview venues and timing was accommodated according to the respondents' preferences. Due to the ongoing COVID-19 pandemic, all relevant regulations were diligently followed. Interviews were conducted through video-calling technology. The research adhered closely to ethical standards, which encompassed the issuance of an informed consent letter outlining the study's details and the researcher's expectations. Respondents were under no obligation to participate and had the liberty to withdraw from the interview at any point.

The interview schedule was structured to tackle the research inquiries. The interviews were recorded and later transcribed, and the resulting data was subjected to a thematic analysis to uncover the research findings.

1.7. LIMITATIONS OF THE STUDY

This study was confined to the geographic area of KwaZulu-Natal, and larger metropolitan areas like Cape Town and Johannesburg were not part of this research. The study focused on the three major companies that work closely with the Department of Transport KwaZulu-Natal (DOTKZN). The study did not consider all Civil Engineering companies in KwaZulu-Natal. Since this study adopted a qualitative approach, the findings cannot be extended to all Civil Engineering companies in South Africa.

1.8. SIGNIFICANCE OF THE STUDY

When considering that vehicles are in use for only 5% of the time and that a substantial number of fatalities stem from human driving mistakes, it becomes clear that the problem is not inherent to the vehicles. Instead, the problem can be reframed as how cars are used or underutilized. If vehicles have the capability to operate autonomously, it raises the question of why they are left idle in front of homes and offices. It appears logical that employing autonomous vehicles as shared resources can lead to more sustainable and safer modes of transportation.

With its distinct geographical, infrastructural, and societal characteristics, KwaZulu-Natal represents a compelling microcosm for assessing the potential impact of autonomous vehicles. This study's findings are expected to provide a valuable understanding of how the implementation of autonomous vehicles can be optimized to suit this region's specific needs and challenges. Professional relevance for Civil engineers and other professionals in KwaZulu-Natal, this study is particularly relevant, as it may guide their practices, ensuring that they remain updated and adaptive in a field marked by rapid technological advancements. The practical implications of this study extend to policymakers, urban planners, and civil engineering professionals. The findings are anticipated to inform evidence-based decision-making, facilitating the development of policies and infrastructure that can accommodate autonomous vehicles effectively, thereby contributing to the region's economic and social development. As autonomous vehicles evolve and reshape transportation landscapes globally, this research anticipates and prepares for the future, offering insights that will be increasingly relevant in the coming years.

1.9. STRUCTURE AND OUTLINE OF THE STUDY

Chapter One offers an overview of the research study, presenting the background, problem statement, motivation, research aims, and objectives. The research questions were subsequently articulated, and the significance and limitations of the study were upfront.

Chapter Two presents the literature review conducted to gain further insight into the topic. This chapter identified the key factors affecting the impact of Autonomous Vehicles on KwaZulu-Natal roads. These factors include levels of automation, motives for autonomous vehicles, safety associated with autonomous vehicles, security associated with autonomous vehicles, social dilemmas, user acceptance, technical development, cost of implementation, and environmental impact of autonomous vehicles.

Chapter Three details the research methodology, explaining the research approach, design, sampling procedures, data collection techniques, and data analysis methods used in this study. The data was gathered through semi-structured interviews and subsequently analyzed by the researcher.

Chapter Four unfolds the interview-derived results and engages in a thorough discussion of these findings. This chapter examines the alignment of participant responses with the literature and research objectives introduced in the study.

Chapter Five, the study's conclusions and recommendations take center stage, evaluating the extent to which the research questions and objectives have been addressed. Furthermore, this chapter will expound upon suggestions for future research and areas for exploration.

1.10. CHAPTER SUMMARY

Autonomous vehicles hold immense significance owing to their ability to elevate road safety, alleviate traffic congestion, enhance mobility options for seniors and individuals with disabilities, limit environmental footprints, stimulate economic productivity, and reshape the paradigms of urban planning and transportation services. Nevertheless, it is imperative to confront and address the formidable challenges linked to safety, regulatory frameworks, and ethical considerations to ensure the seamless integration of autonomous vehicles into our transportation systems.

Due to this complexity, this research attempts to explore the factors that influence the successful implementation of autonomous vehicles within the distinctive context of KwaZulu-Natal. This investigation is approached from the perspective of civil engineers actively engaged in the planning and execution of road infrastructure projects, with the overarching goal of illuminating the complex interplay between cutting-edge technology and established engineering practices in this South African province.

CHAPTER TWO: LITERATURE REVIEW

2.1. INTRODUCTION

This research aims to examine pertinent literature concerning the social impacts of autonomous vehicles, different levels of automation, drivers behind the adoption of automation, safety considerations, security aspects, social implications, user acceptance, technical advancements, and cost implications. The exploration of these topics will provide valuable insights into the effectiveness and viability of implementing this emerging technology.

Getting an overview of the existing models and their influencing factors found in previous research articles will assist in identifying the limitations in the literature and areas that will require further attention.

This literature research will mainly focus on aspects that play a role in user acceptance of autonomous vehicles, and this will help set out the research methodology. Understanding the factors that play a role in advance allows the focus on the underlying reasons for these factors.

2.2. LITERATURE RESEARCH

The literature discussed in this review used literature research, to gain a comprehensive understanding of the contributions in the field, it was necessary to review the literature within the field. This review resulted in articles that were published between 2001 and 2023 and found using the systematic keywords search, and the search terms were "Autonomous driving," "Self-driving car," and "Driverless car."

2.3. RELEVANT TOPICS

This research section aims to enhance our understanding of the autonomous vehicles field, evaluate the technology's acceptance, and identify the previously investigated research gaps. To do so, it will provide a background on autonomous vehicles and the acceptance of the technology from a general level. The findings will also support understanding the efficiencies of autonomous vehicles and their safety aspects and indicate the social impacts of introducing autonomous vehicles in South African road infrastructure.

Autonomous vehicle technology could have the potential to revolutionize the way South Africans commute. According to the Deonarain (2019) report published by the Department of Trade and Industry, implementing autonomous vehicle technology could considerably reduce traffic congestion in South African cities. Such a reduction would lead to shorter journey times and improved commuter efficiency and safety, as autonomous vehicles use artificial intelligence to make decisions about routes, speed, and safety. In addition, there is potential for autonomous vehicles to reduce the cost of commuting, as these vehicles can be operated more efficiently due to their ability to stay in a lane and maintain a safe distance between vehicles (Deonarain, 2019). Furthermore, implementing autonomous vehicle technology could improve environmental benefits such as reducing emissions and fuel consumption resulting from more efficient driving (Deonarain, 2019).

The South African government faces numerous potential challenges in implementing Autonomous Vehicle (AV) technology. According to Sutherland (2020), South Africa is falling behind other countries in developing and implementing AV technology due to the lack of technical skills and technological infrastructure. This lack of technology and expertise could lead to potential risks to the safety of citizens. The South African government may struggle to develop the regulatory framework and legal infrastructure to support Avs (Sutherland, 2020). South Africa lacks a dedicated regulatory body for autonomous vehicles, and multiple government departments are responsible for regulating the technology. As such, ensuring that regulations are up-to-date and consistent could be difficult. The cost of implementing AV technology could be a significant challenge for South African governments (Sutherland, 2020). Implementing AVs and the necessary infrastructure, such as sensors and communication systems, could be too expensive for the government (Sutherland, 2020).

This technology can severely reduce the number of collisions on South African roads due to its ability to autonomously detect and react to environmental hazards (Kettles and Van Belle, 2019). Cutting-edge sensors, such as radar and cameras, allow autonomous vehicles to distinguish between objects in their environment, including other vehicles, pedestrians, and cyclists. Thus, the vehicle can take evasive or braking action to avoid a collision (Kettles and Van Belle, 2019).

2.4. DEFINITIONS

This section provides definitions of the efficiencies of autonomous vehicles, the safety aspects, and the social impacts of introducing autonomous vehicles in the South African road infrastructure.

This report utilizes the following definition by Frazzoli (2001):

"Autonomous vehicles can drive without human intervention or monitoring in an unpredictable, uncertain, and open traffic environment designed, built, and populated by and for humans (Frazzoli, 2001)."

2.4.1. Autonomy

Autonomy is the state or ability to be self-governing or acting distinctly from others. Applying this to vehicles will enable the vehicle to operate without human interactions. Artificial intelligence accomplishes this task (Mahmoud Zadeh et al., 2019).

2.4.2. Self-driving vehicle

It is a vehicle that can steer a course, accelerate, and brake with limited or no interactions from a driver (Mahmoud Zadeh et al., 2019).

2.4.3. Autonomous vehicle

Vehicles that can drive themselves from point A to point B without the interactions of a driver (Faisal et al., 2019). Autonomous vehicles can move while sensing the surroundings and identifying and detecting objects and the environment around the vehicle (Van Brummelen et al., 2018). The vehicle utilizes the Global Positioning System (GPS) to determine its location accurately and constructs an environment model (Zmud and Sener, 2017, Van Brummelen et al., 2018). This model enables the vehicle to navigate around obstacles.

2.4.4. Fully Autonomous

It can be categorized into user-operated and driverless vehicles. Fully autonomous requires no human interaction (Modigh, 2021).

2.4.5. Ride-sharing

Ride-sharing is defined as passengers sharing vehicles to decrease the cost of individual journeys, CO2 emissions, and traffic congestion (Siddiq and Taylor, 2022).

2.4.6. Ride-hailing

It is a service provided to people who need transportation from one point to another. These services are usually booked on mobile devices and charged according to the distance and time it takes for the ride (Siddiq and Taylor, 2022).

2.4.7. Autonomous Taxi service

It is defined as a fully autonomous vehicle used as public transport, where users can book rides through their mobile devices (Siddiq and Taylor, 2022).

2.5. AUTONOMOUS VEHICLES

Autonomous vehicles lack direct driver input and rely on sensors, cameras, LIDAR, GPS, and other onboard technologies for operation. They are part of Advanced Driver Assistance Systems (ADAS), transferring driving responsibilities from the driver to the vehicle for convenience and safety (Zmud and Sener, 2017).

According to studies conducted by Leathrum et al. (2018), Autonomous vehicles provide numerous benefits over systems requiring human control. Driverless cars could be safer since the system does not suffer from a lack of attention. This has been supported by Chater et al. (2018), stating that autonomous vehicles, which promise significant gains in human welfare through improved mobility and safety, bring to light fundamental challenges for cognitive science and artificial intelligence, not just in sensing and control.

The autonomous vehicle can be used for various purposes, including (Hucko, 2017)

- Owned for personal transportation,
- Personal-mobility service on demand,
- Rental vehicles for transport needs and short-term mobility,
- Transportation of commodities and goods,
- Local commercial delivery services,
- Vehicles for persons with disabilities,
- Corporations and other entities can own fleets,
- Urban use vehicles.

Autonomous Vehicle Technology (AVT) is a rapidly advancing technology that has gained more attention over the past few years. AVT is a software, hardware, and sensor system enabling a vehicle to operate with little human input. According to Bimbraw (2015), the technology can be divided into four categories: perception, path planning, actuator control, and system integration. The perception category consists of sensors and algorithms that collect data from the environment and identify objects such as pedestrians, traffic signs, and lane markings. Path planning involves using algorithms and digital maps to identify the best route for the vehicle based on the surrounding environment. The actuator control category controls the vehicle's speed, direction, and acceleration. Lastly, system integration combines all the components to ensure the vehicle operates safely and efficiently. AVT promises to revolutionize the transportation industry by providing a safer, more accessible, and more efficient mode of transportation.

Autonomous vehicle technology can potentially revolutionize how people move around South Africa. Morrison and Van Belle (2020) stated that autonomous vehicle technology could provide numerous benefits to consumers in South Africa. These benefits include improved safety, efficiency, reduced emissions, and accessibility. Autonomous vehicles are equipped with sophisticated sensors, cameras, and advanced driving algorithms, empowering them to navigate the roads with remarkable safety and efficiency. These state-of-the-art technologies work in tandem to perceive the surrounding environment, analyze data, and make informed decisions in real time, allowing autonomous vehicles to adapt to changing circumstances and avoid potential hazards. This technology can help reduce the number of traffic accidents, which is especially important in South Africa, given the high rate of road fatalities.

Furthermore, autonomous vehicles can be designed to be more fuel-efficient and produce fewer emissions than traditional vehicles, helping to protect the environment. Autonomous vehicles have the potential to improve accessibility, particularly for those with disabilities or special needs.

Autonomous vehicles can be designed to be wheelchair-accessible and can be programmed to recognize signs and landmarks to facilitate navigation.

2.6. LEVELS OF AUTOMATION

The potential for autonomous vehicle technology to revolutionize transportation in South Africa is immense. Currently, South Africa has no policy for driving automated vehicles; thus, the international standard used worldwide comes from the Society of Automotive Engineers. The international standard J3016 is currently being used to define levels of automation worldwide. This policy is accepted widely in the industry and has been incorporated into many government policies. The US National Highway Traffic Safety Administration, or NHTSA, also incorporates this in its federal policy (National Highway Traffic Safety Administration, 2016).

Levels of automation in autonomous vehicles refer to the extent to which a vehicle can operate without human intervention (SAE, 2018). The Society of Automotive Engineers (SAE, 2018) has defined six levels of automation, ranging from no automation to full automation. These levels are based on the vehicle's ability to handle driving tasks and the driver's responsibility for controlling the vehicle. At the lower levels of automation, the driver is responsible for most driving tasks. Without human intervention, the vehicle can handle most or all driving tasks at higher levels (SAE, 2018). Comprehending the levels of automation is fundamental for determining the potential and constraints of autonomous vehicles and establishing the necessary regulations and standards to ensure their safe operation.

The most significant distinction between the levels of automation is the step from SAE Level 2 to SAE Level 3, which splits Human Driver Systems from Automated Driving Systems, as seen in ***Table 2-1*** below.

Table 2-1: Summary table of levels of driving automation according to SAE standard J3016 (National Highway Traffic Safety Administration, 2016).

SAE Level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	Monitor of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment						
0	No automation	The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems.	Human Driver	Human Driver	Human Driver	N/A
1	Driver assistance	The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectations that the human driver performs all remaining aspects of the dynamic driving task.	Human Driver and System	Human Driver	Human Driver	Some-Driving Modes
2	Partial automation	The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectations that the human driver performs all remaining aspects of the dynamic driving task.	System	Human Driver	Human Driver	Some-Driving Modes
Automated driving system ("system") monitors the driving environment.						
3	Conditional automation	The driving mode-specific performance by an automated driving system of all aspects of the driving task with the expectation that the human will respond appropriately to a request to intervene.	System	System	Human Driver	Some-Driving Modes
4	High automation	The driving mode-specific performance by an automated driving system of all aspects of the driving task, even if a human driver does not respond appropriately to a request to intervene.	System	System	System	Some-Driving Modes
5	Full automation	The driving mode-specific performance by an automated driving system of all aspects of the driving task under all roadway and environmental conditions that can be managed by a human driver.	System	System	System	All Driving Modes

The SAE international standard J 3016 defines six levels of driving automation as shown in ***Table 2-1*** above, ranging from level zero (no automation) to level five (full automation). The levels of automation by SAE International are described in detail as follows (National Highway Traffic Safety Administration, 2016):

2.6.1. Level Zero or No Automation

Describe most cars on the road today; you can include all the cars without at least adaptive cruise control. In this case, the human driver controls the vehicle's overall performance, including its longitudinal and lateral dynamics. Meaning they are always responsible for the car's performance (National Highway Traffic Safety Administration, 2016).

2.6.2. Level One or Driver assistance

Defines cars with a driver assistance system of either steering, acceleration, or braking. The systems monitor just some of the total driving environment. The human will supervise the system and perform all remaining driving tasks. The handoff can happen anytime, and the driver must always be ready to take over. This level is typically associated with cars that offer adaptive cruise control, which many high-end cars now offer as an option—for example, Tesla (National Highway Traffic Safety Administration, 2016).

2.6.3. Level Two or Partial automation

Defines cars with multiple driver assistance systems that include steering, acceleration, or braking. The system monitors just some of the total driving environment. A human must supervise the system and perform all remaining tasks (National Highway Traffic Safety Administration, 2016). Handoff can happen anytime, and the driver must always be ready to take over; this includes Tesla's autopilot, Mercedes Benz Drive pilot, Infinity's active lane control, and BMW's Active Driving Assistance Plus (Soomro, 2021).

Car and Driver Magazine put these semi-autonomous cars to a rigorous test. Car and Drivers said that Tesla came out the clear winner with the lowest number of lean control interruptions and the only car with lane change capability. They differ slightly in how they operate but mostly in how long they stay engaged if your hands are off the wheel. Below, ***Table 2-2*** illustrates the Car and Drive Magazine test results.

Table 2-2: Test results: Car and Drive- Semi-Autonomous Comparison (DON, 2016).

Test Results				
	BMW	INFINITI	MERCEDES	TESLA
Cruise-Control-Setting Range, Mph	19-106	19-109	20-118	18-89
Cruise-Control Response to Lane Intruder	EXCELLENT	EXCELLENT	EXCELLENT	EXCELLENT
Number of Lane-Control Interruptions On 50-Mile Route	56	93	58	29
Lane Control at Night, In the Rain	GOOD	GOOD	GOOD	GOOD
Wheel Force to Regain Steering, LB	2	4	3	4
Lane-Change Ability	NO	NO	NO	YES
Parking Assistance	YES	NO	YES	YES

2.6.4. Level Three or Conditional automation

The car will have multiple driving assistance systems, monitor the complete driving environment, and perform all the driving tasks. However, the human driver is expected to respond appropriately to request intervention. Like Level Two, however, the car should be able to perform many more driving tasks and perhaps give the human more notice when it needs assistance. Today, in Level

Two, the cars are expected to be able to hand off control to humans at any time. There are no cars with Level Two conditional automation available (National Highway Traffic Safety Administration, 2016).

2.6.5. Level Four or High automation

The car will have multiple driver assistance systems, monitor the complete driving environment, and perform all the driving tasks. Even if the human driver will not respond appropriately to the request to intervene, it is very close to full automation; however, this assumes that the car is perhaps operating in a controlled area (National Highway Traffic Safety Administration, 2016). For example, ones with limited speed or, certain times of the day, or under certain weather conditions

2.6.6. Level five or Full automation

The car will have a full-time automated driving system and perform all driving tasks under all roadways and environments. The human can manage the system and do not need to intervene (National Highway Traffic Safety Administration, 2016).

2.7. MOTIVES FOR AUTONOMOUS VEHICLES

An estimated 195,085 deaths were recorded on South African roads between 2008 and 2022 (RTMC, 2022, RTMC, 2017). Most of these cases were a result of human error. A road traffic crash is an outcome of the complex interplay between multiple factors encompassing the components of the system, namely roads, the environment, vehicles, and road users. The dynamic interaction and interdependence of these elements contribute to the occurrence of road accidents. (RTMC, 2017). Over the past few years, there has been a notable surge in interest regarding vehicle dynamics and stability among various stakeholders, including automotive engineers, automobile manufacturers, government entities, public safety organizations, and the general public. This heightened attention reflects the recognition of the crucial role played by these domains in ensuring optimal performance, safety, and overall satisfaction in the automotive industry.

According to the Road Traffic Management Corporation (RTMC, 2020), there were 12,921 deaths on South African roads in 2020, a decrease from the 14,071 deaths recorded in 2019. The high incidence of road fatalities in South Africa can be attributed to a multifaceted blend of contributing factors. Reckless driving, characterized by careless and irresponsible behavior on the road, poses a significant risk to road safety. Furthermore, the occurrence of drunk driving, which involves individuals operating vehicles while under the influence of alcohol or drugs, further compounds the issue. Speeding, another crucial factor, increases the likelihood of accidents and intensifies the severity of injuries sustained. Moreover, the poor condition of road infrastructure, such as inadequate signage, potholes, and lack of maintenance, contributes to the overall risk and danger on the roads. Addressing these underlying issues is paramount in order to improve road safety and reduce the tragic toll of road fatalities in South Africa.

The transportation system in Foshan, China, faces significant fragility, primarily resulting from ineffective linking arrangements, a scarcity of public transport vehicles, and impractical car designs. The lack of priority given to public transport and the declining service standards exacerbate the issue, leading to decreased attractiveness among the city's residents (Annex, 2018). This can be compared to South Africa because it has a similar situation with the transportation infrastructure.

South Africa's Road death toll is among the highest in the world. In 2013, there were over 34.1 deaths per 100,000 population, considered a significant public health issue in the country Matzopoulos et al. (2015). Despite the various efforts that have been made to reduce this figure, the number of road fatalities remains high. According to Matzopoulos et al. (2015), many factors contribute to the high number of road-related deaths in South Africa. ***Figure 2-1*** below shows the factors contributing to the high number of road-related deaths in South Africa.

Figure 2-1: Factors contributing to the high number of road-related deaths in South Africa (Matzopoulos et al., 2015).

South Africa continues to experience a high number of road-related deaths, with 39 deaths per 100,000 people in 2018 (Huang et al., 2019). In 2018, it was estimated that about 17% of all deaths were caused by road-related accidents. A significant portion of the population has been lost due to road-related fatalities, likely impacting South African society significantly (Huang et al., 2019). The loss of life can be felt in various ways, such as the emotional impact of the loss of a loved one, the financial costs associated with funeral services, and the decline in the quality of life due to the absence of productive individuals.

Traffic congestion accounted for 87 billion dollars in production costs in the United States alone in 2018 (INRIX, 2019). According to INRIX (2019), the average Bostonian driver lost 164 hours in the last year (2018) due to traffic congestion. Autonomous vehicles provide substantial benefits over conventional cars. Improved traffic safety, which could reduce the 42,000 annual total deaths due to traffic accidents in the United States alone (Chu et al., 2015), significantly better fuel economy Rosenzweig and Bartl (2015), and car sharing Ross and Guhathakurta (2017) are just a few of the many benefits that the introduction of self-driving cars brings to the table. Virtually every major car manufacturer has started working on autonomous driving, and it is expected that it won't take long for most manufacturers to bring their first self-driving cars to market.

In recent years, there has been a significant acceleration in the development of autonomous vehicles. This can be attributed to the increasing feasibility of the technology and the extensive literature that identifies numerous significant advantages that autonomous vehicles can offer our society. Traffic safety has always been a significant issue worldwide. One of the most apparent benefits of autonomous vehicles is the improvement of traffic safety, which could save lives and be economical (Kaan, 2017).

Autonomous vehicles offer more than just safety benefits; another example is the significant improvement in fuel economy that can be achieved by autonomous vehicles. These vehicles can effectively tune their acceleration and deceleration profiles to reduce wasted fuel (Hucko, 2017) while also taking advantage of their capabilities to dive closer to each other, allowing the phenomenon called "Platooning." Platooning gives these vehicles the advantage of reducing air resistance, thus making them more fuel-efficient. The traffic flow and the capacities within the highways are also improved through this phenomenon (Le Vine et al., 2015, Luettel et al., 2012).

Autonomous vehicles could also provide better mobility for people who cannot drive themselves or do not have someone to drive them due to availability. Examples of this are people with disabilities who cannot drive due to their disabilities, people who have lost their driving privileges due to their age, or people who are too young to drive themselves (Le Vine et al., 2015). Autonomous vehicles will also benefit those who can drive but are under the influence of alcohol or other substances.

One of the other significant factors that are very beneficial to the user is the reduction of stress (Litman, 2020). Autonomous vehicles driving by themselves will allow people to rest or do work while traveling instead of concentrating on the road (Litman, 2020). It is also beneficial when traveling long distances by car, which could lower driver fatigue. The driver could entertain him or herself while on the trip or do something productive, making the traveling more efficient.

Autonomous vehicles would also encourage sharing rides, as they would quickly move between places to pick people up. Alessandrini et al. (2015) suggest that vehicles are only a tiny part of people's lives and state that vehicles are, on average, parked for almost 22 hours of the day. Larry Burns, Columbia University- New York, claims that only 15 percent of vehicles would be required on Ann Arbor roads if car sharing was implemented efficiently(VASILASH, 2018). Litman (2020) argues that self-driving taxis would be more efficient and cost-effective for people who travel less than 8,050 kilometers (5,000 miles) a year. However, people prefer the convenience of owning their own vehicles. Society has a pretty strong consensus about the benefits of self-driving vehicles and prefers some benefits over others.

2.8. Safety Associated With Autonomous Vehicles

The safety aspect of autonomous vehicles represents how the system can operate and protect passengers and other road users in everyday vehicle operations, not including the resistance against active or negative manipulation of the operating system. This will be analyzed in the following subsection.

Autonomous vehicles will be designed to assist a driver and make driving simpler and safer. The major challenge is how to design these systems so that they can operate and interact with a driver with a minor distraction from the driving task.

Sabaliauskaite et al. (2018) proposed that a Six-Step Model could enable comprehensive safety and security analysis. ***Figures 2-2, 2-3, and 2-4*** below show the proposed six-step model.

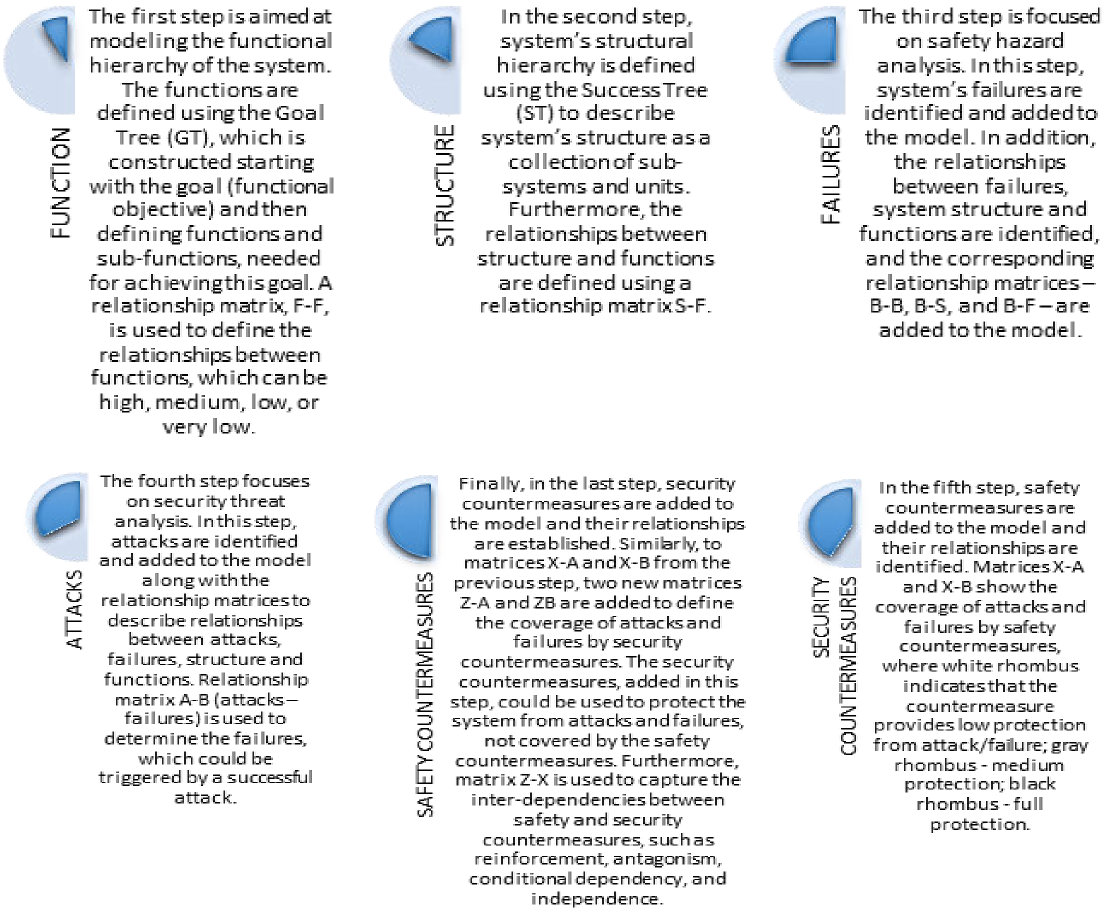


Figure 2-2: Six-Step Model- Procedure of Model (Sabaliauskaite et al., 2018).

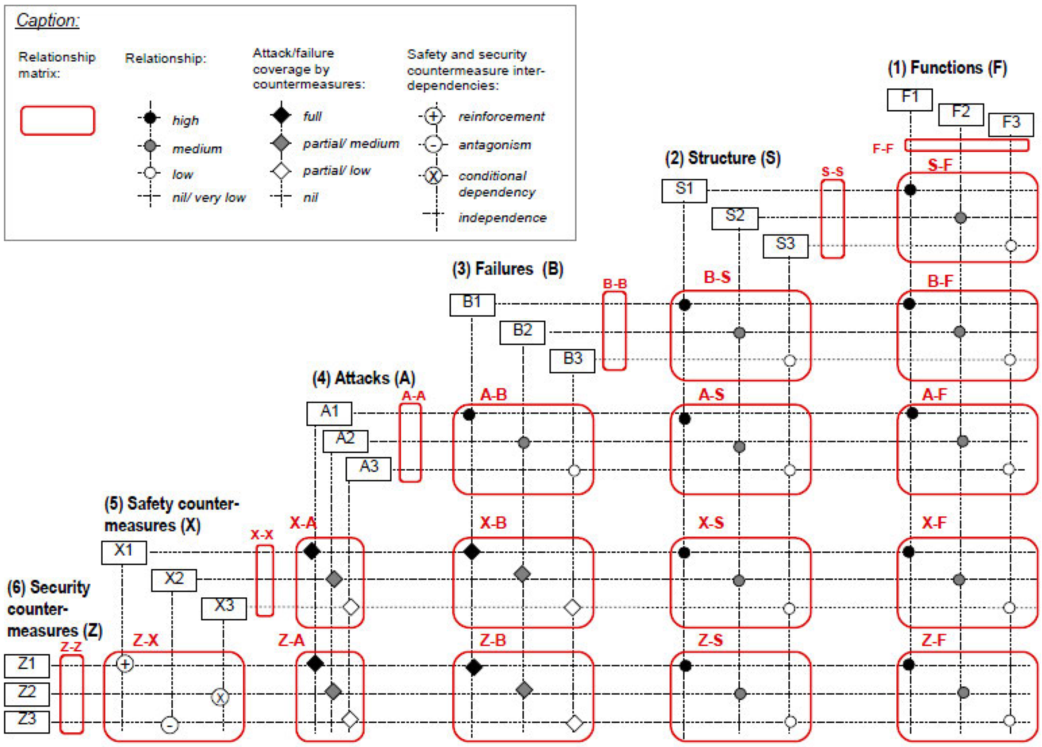


Figure 2-3: The Six-Step Model (Sabaliauskaite et al., 2018).

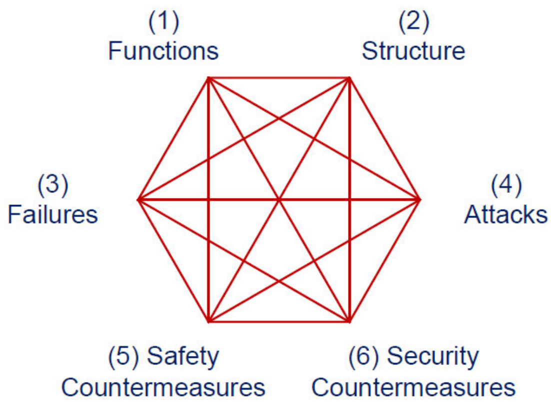


Figure 2-4: Relationships among hierarchies of the Six-Step Model (Sabaliauskaite et al., 2018)

The vital transition of the driving task from and to the human driver is critical to safety. The system must allow enough time in all conditions for this transition. A study by Merat et al. (2014) on the safety transition points to at least 5 seconds recommends 40 seconds, equal on the Swiss highway 500m and 1333m, respectively of travel distance (Speed limit 120km/h). Human drivers in conventional vehicles perceive these distances as irrational and may misunderstand them as a signal for the right of way, which will provoke risky driving. The more driving tasks and driving time humans transfer to autonomous vehicles, the more they lose practice in driving, thus leading to longer required transition times and larger safety margins.

The next issue can occur when the interaction with autonomous systems is not clearly understood or if the system's human mental model of the machine is inaccurate regarding its capabilities and limits (Bösch, 2018). Another safety aspect is handling passengers under guardianship, including elderly and disabled passengers. Their decisions and behaviors are critical as passengers must be controlled and handled safely.

Autonomous vehicles have the ability to enhance road safety through various means. The following is taken into consideration (Kalra, 2017):

- Reduced human error: Human error is a significant cause of road accidents. Autonomous vehicles can mitigate the risk of accidents resulting from human error by either removing the need for a human driver or by aiding the driver through advanced safety features.
- Improved reaction time: Autonomous vehicles can react much faster than human drivers, which can help prevent accidents. They can identify and respond to possible hazards faster and more accurately than a human driver.
- Advanced sensors and cameras: Autonomous vehicles are provided with enhanced sensors and cameras that can detect and respond to their surroundings. These sensors can detect obstacles, pedestrians, and other vehicles and help the vehicle avoid collisions.
- Constant monitoring: Autonomous vehicles constantly monitor their surroundings, which can help prevent accidents. They can identify and respond to changes in traffic patterns, road conditions, and weather conditions.
- Improved road infrastructure: Autonomous vehicles have the capability to establish communication with other vehicles and with road infrastructure components, including traffic lights and road signs. These can help improve traffic flow and reduce the risk of accidents.

2.9. SECURITY ASSOCIATED WITH AUTONOMOUS VEHICLES

As with any technological advancement, ensuring the security of autonomous vehicles is of utmost importance. The system's security represents the ability to withstand active and negative manipulation. The best example is the resistance to hacking attempts. These would also include attempts to steal or damage the vehicle. Autonomous vehicles are highly connected to the internet and require a lot of security features to create a safe environment for these vehicles (Bösch, 2018). Examples of problems associated with the security of autonomous vehicles are hacks of the vehicle, including taking over the vehicle remotely whistle driving (Greenberg, 2015). To overcome these dangerous hacks, the vehicle with a driver will require a “Kill Switch” This button is pressed in an emergency and would instantly return control to the vehicle, allowing the driver to safely stop the vehicle in an emergency (Bösch, 2018).

Security is a critical aspect of autonomous vehicles. Below are some of the key security considerations that are associated with autonomous vehicles.

2.9.1. Cybersecurity:

- Autonomous vehicles rely heavily on software and communication systems, making them vulnerable to cyber threats (Khan et al., 2022).
- Implement robust cybersecurity measures to protect the vehicle's systems from hacking, data breaches, and malicious attacks (Petit, 2019).
- Employ techniques such as encryption, firewall systems, intrusion detection systems, and secure communication protocols (Petit, 2019).

2.9.2. Authentication and Access Control:

- Secure access control mechanisms should be in place to prevent unauthorized physical access to the vehicle's components (Koschuch et al., 2019).
- Install robust authentication methods, such as biometric identification or multi-factor authentication, to guarantee that only authorized individuals can gain access to the vehicle (Koschuch et al., 2019).

2.9.3. Firmware and Software Updates:

- Regularly update the vehicle's firmware and software to address any security vulnerabilities discovered post-production (Khurram et al., 2016).
- Establish secure update mechanisms to prevent unauthorized or tampered updates that could compromise the vehicle's security (Sun et al., 2021).

2.9.4. Data Protection and Privacy:

- Protect the sensitive data collected by autonomous vehicles, such as location information and passenger data (Sun et al., 2021).
- Utilize data encryption, access controls, and anonymization methods to safeguard data privacy and deter unauthorized access or misuse (Sun et al., 2021).

2.9.5. Sensor and Perception Security:

- Safeguard the sensors used in autonomous vehicles to ensure the accuracy and integrity of perception data (Liu et al., 2019).
- Implement measures to detect and prevent tampering or spoofing of sensor inputs, as compromised data can lead to unsafe driving decisions (Liu et al., 2019).

2.9.6. Redundancy and Safety Measures:

- Incorporate redundancy and fail-safe mechanisms to ensure the safe operation of autonomous vehicles in the event of system failures or cyberattacks (Khan et al., 2022).

- Implement backup systems, redundant sensors, and real-time monitoring to detect and mitigate potential safety risks (Khan et al., 2022).

2.9.7. Industry Standards and Collaboration:

- Follow established industry standards and best practices for autonomous vehicle security (Petit, 2019).
- Collaborate with cybersecurity experts, automotive manufacturers, regulators, and researchers to stay updated on emerging threats and security solutions (Petit, 2019).

2.9.8. Ethical Considerations:

- Consider the ethical implications of autonomous vehicles, such as decision-making algorithms, in critical situations (Ryan, 2019).
- Ensure that security measures align with legal and ethical frameworks to prioritize the safety of passengers, pedestrians, and other road users (Ryan, 2019).

Ensuring the security of autonomous vehicles necessitates a comprehensive approach encompassing a range of measures. This includes implementing robust technological safeguards, facilitating continuous updates to address emerging vulnerabilities, fostering stakeholder collaboration, and ensuring compliance with industry standards. By adopting this holistic approach, the safe and secure operation of autonomous vehicles can be ensured.

2.10. SOCIAL DILEMMA OF AUTONOMOUS VEHICLES

As the world enters a new technological era due to recent advancements in artificial intelligence, autonomous vehicles are being developed in a way unseen before. Autonomous vehicles promise smarter, safer, and more efficient transportation but bring numerous social dilemmas. With the emergence of this technology, many ethical, social, and regulatory considerations will need to be considered.

Autonomous Vehicles should reduce traffic accidents. However, the vehicle may be put into a predicament to choose between two evils, such as running over pedestrians or sacrificing itself and the passenger to save them (Bonnefon et al., 2016). The ethical implications of autonomous vehicles on road safety are essential, particularly since they are becoming increasingly prevalent on our roads. The moral decision of defining this algorithm to assist the vehicle in making such a decision is tough (Martinho et al., 2021). In online surveys, participants approve of autonomous vehicles that sacrifice the driver to save many others. A practical approach aims to preserve the most life, but respondents would prefer not to buy these kinds of cars. They don’t want regulations that require self-sacrificing algorithms. Such regulations would make them less willing to buy self-driving cars. The rise of autonomous vehicles creates a social dilemma: Roads would be much safer if more autonomous cars existed. However, programming that would make driving safer might prevent people from buying these vehicles. Imagine yourself in the car shopping process, faced with a decision between two options: a car that occasionally puts the driver at risk and a car that prioritizes the passenger's safety above all else.

Below is a study by Mechanical Turk for USA residents only between June and November 2015. This study was conducted through six online surveys (Bonnefon et al., 2016).

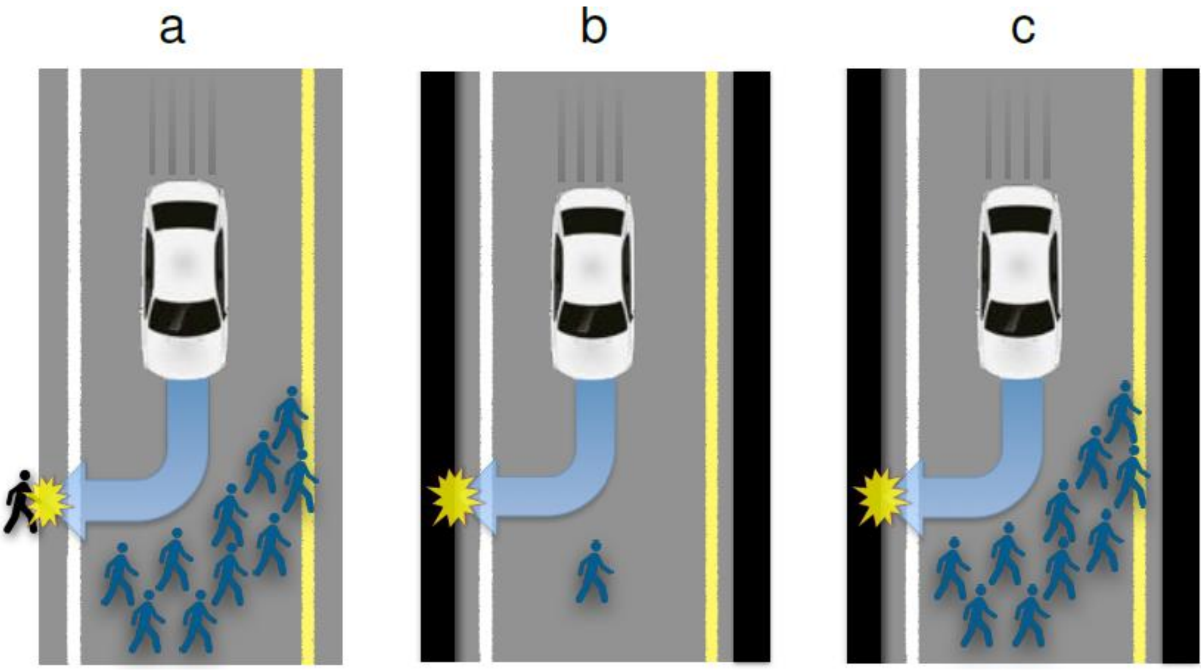


Figure 2-5: Three traffic situations involving imminent unavoidable harm (Bonnefon et al., 2016).

Figure 2-5 above shows three traffic situations involving imminent unavoidable harm. The car must decide between:

a) killing several pedestrians or one passerby,
b) killing one pedestrian or killing its passenger,
c) killing several pedestrians or killing its passengers.

The six online surveys were based on the above situations explained above.

The greater good versus the life of the passenger, Studies 1 and 2 (***Figures 2-6 and 2-7***) are based on this statement. The participants were asked which would be the best way to program the AV's morally, and the participants chose to kill the passenger for the greater good.

The studies were conducted according to the concept of the greater good versus the passenger's life; studies 1 and 2 were based on this statement. When choosing the appropriate way to program the AVs, most people said they would prefer to have them kill their passengers for the greater good. The preference for this option was strong regarding saving more than five lives. (The left panel shows detailed results for ten lives). The results indicated that people were more likely to think that autonomous vehicles should prioritize the greater good than they are to think that they would be instructed to do so automatically. Boxes display the mean's 95% confidence interval (Bonnefon et al., 2016). Below are the findings of Studies 1 and 2.

Figures 2-8, 2-9, 2-10, and 2-11 below illustrate the regulation and procurement (studies 3-6). The 95% confidence interval of the mean is displayed in boxes. Participants in all tests indicated a moral preference for AVs to sacrifice their passengers to save more pedestrians. When people pictured themselves in the AV with a friend, family member, or child, their moral preference remained unaffected. Participants in (a and b) did not express a similar preference for purchasing utilitarian AVs, especially considering their family members riding along with them. Participants in (c and d) disapproved of regulations requiring utilitarian algorithms for AVs and said they would be less likely to buy an AV if such a regulation were in place.

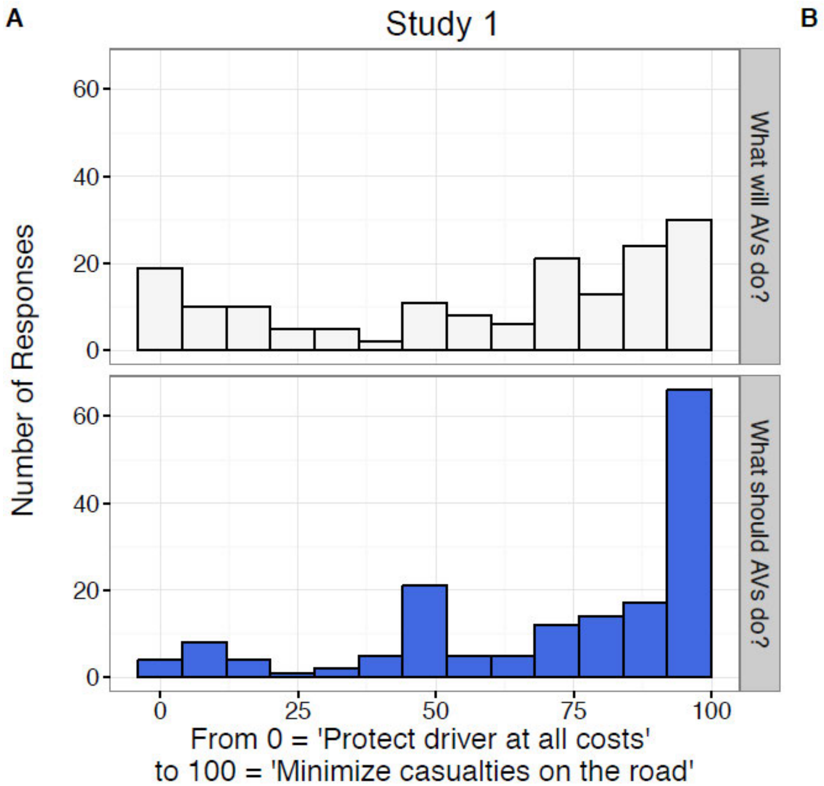


Figure 2-6: What will AVs do? (Bonnefon et al., 2016).

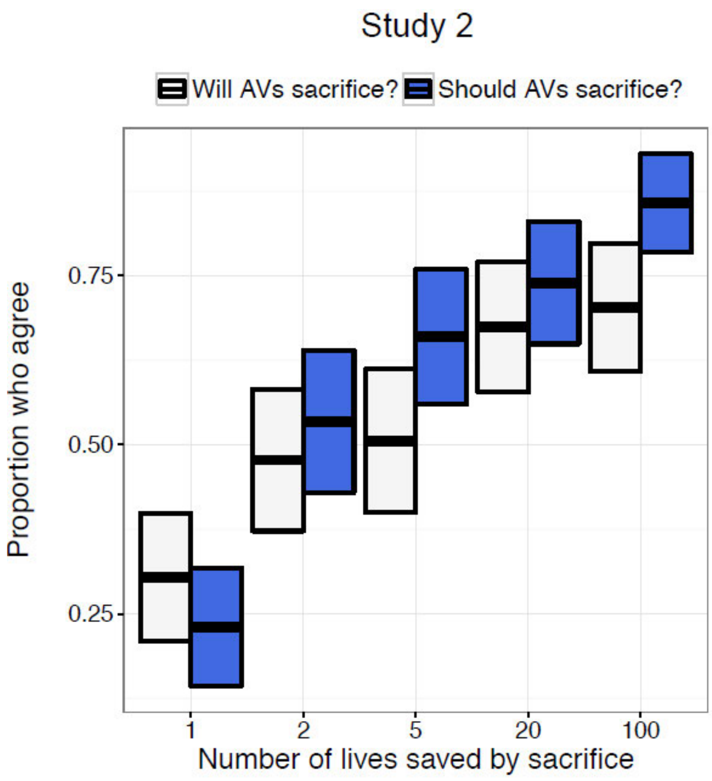


Figure 2-7: Will AVs sacrifice? Should AVs sacrifice? (Bonnefon et al., 2016).

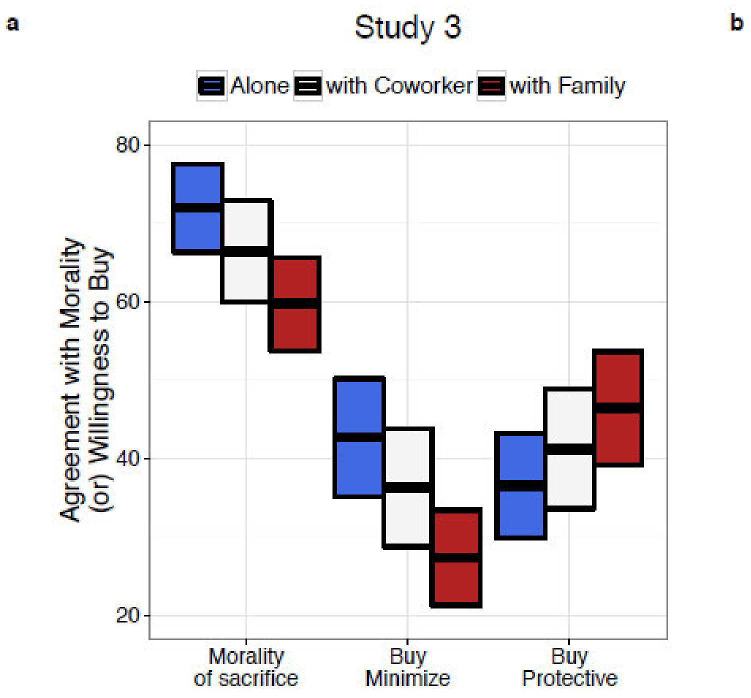


Figure 2-8: Agreement with Morality or Willingness to Buy (Bonnefon et al., 2016).

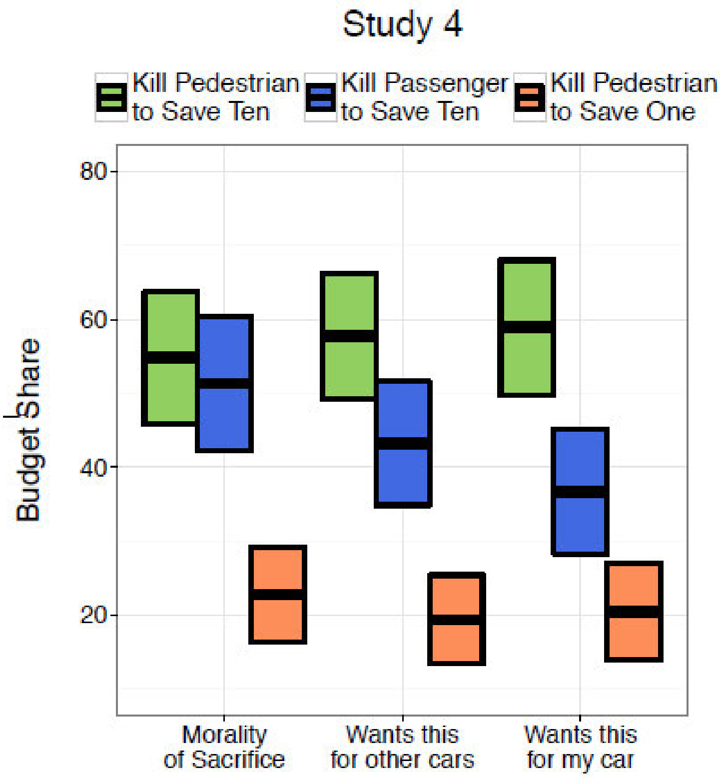


Figure 2-9: Comfort level of an AVs algorithm (Bonnefon et al., 2016).

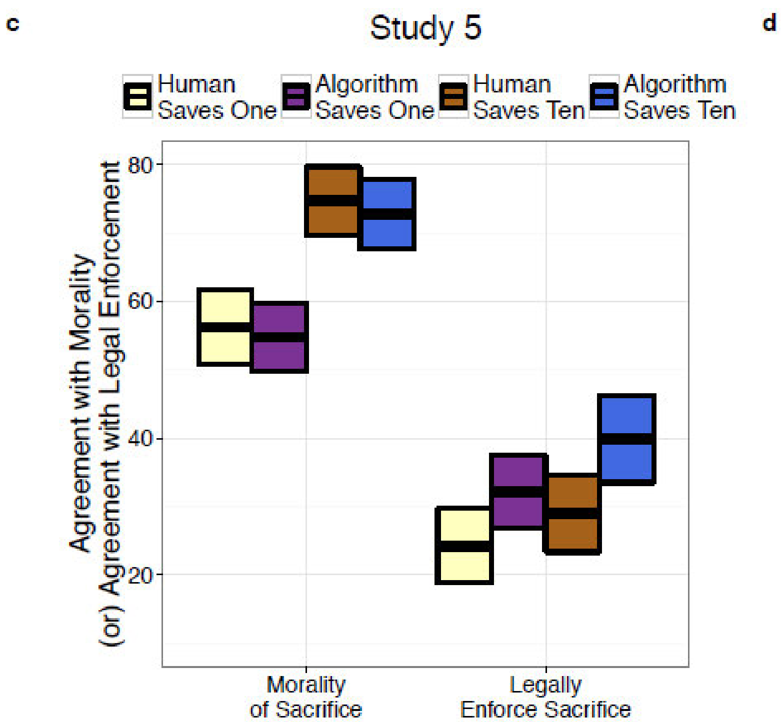


Figure 2-10: Attitudes towards legally enforcing utilitarian sacrifices (Bonnefon et al., 2016).

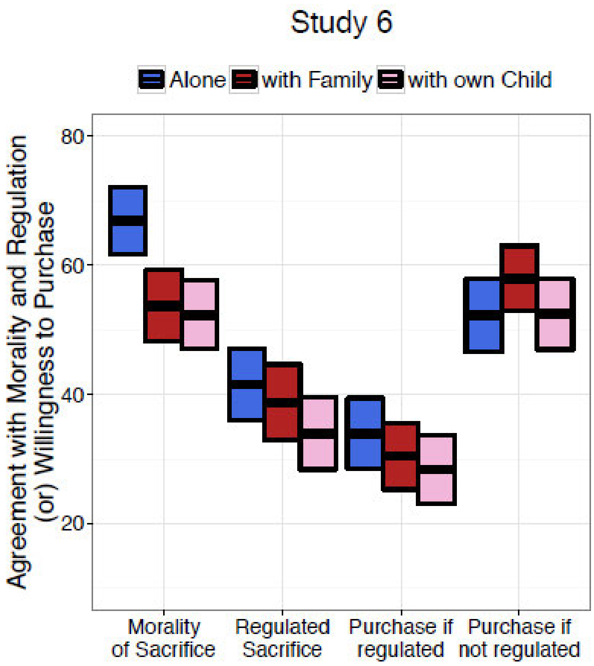


Figure 2-11: Probability of purchasing the AVs whose algorithms had been regulated by the government (Bonnefon et al., 2016).

2.11. User Acceptance Of Autonomous Vehicles

The use of automated vehicles has sparked a new and revolutionary technological boom in transportation. Automated vehicles are gradually becoming mainstream as more households and businesses accept and use them. Automation vehicles have gained immense popularity and attention over the last few years, as they promise to revolutionize the transportation industry (Merat et al., 2017).

The impact of automated vehicles on human behavior and user acceptance is an essential topic in the transportation industry, as it can help inform and shape future policy decisions. Automation vehicles can potentially reduce traffic congestion, improve safety, and reduce overall transportation costs (Merat et al., 2017). Automated vehicles can reduce the time and energy humans need to utilize when operating a vehicle. It can improve users' comfort, convenience, and greater freedom and independence. Moreover, automated vehicles may lead to greater trust between users and the technology, as the vehicles will be able to show consistent and reliable performance (Merat et al., 2017).

User acceptance of automated vehicles is a growing area of research due to the potential for increased safety and efficiency (Smyth et al., 2021). Automation vehicles are equipped with sensors, cameras, and other technology that can detect and respond to the environment around them. Understanding the factors that impact user acceptance of such vehicles is essential for developing effective autonomous systems.

Nikitas et al. (2019) argued that autonomous vehicle usage can have a number of potential social and ethical implications. For example, they suggested that autonomous vehicles could negatively impact road safety, as the decisions taken by autonomous vehicles may not always be optimal from a safety perspective. Furthermore, they argued that autonomous vehicle technology could have potential privacy implications, as personal data collected by the vehicles could be used for various commercial and surveillance purposes. Additionally, they suggested that autonomous vehicles could further exacerbate social inequality, as the wealthy may be able to benefit disproportionately from the technology.

Autonomous vehicle technology (AVT) has the potential to revolutionize transportation but also comes with associated risks and challenges. Ma et al. (2020) investigated the potential risks and challenges of AVT and found that they could be divided into three categories: technical, legal, and ethical, as shown in ***Figure 2-12*** below.

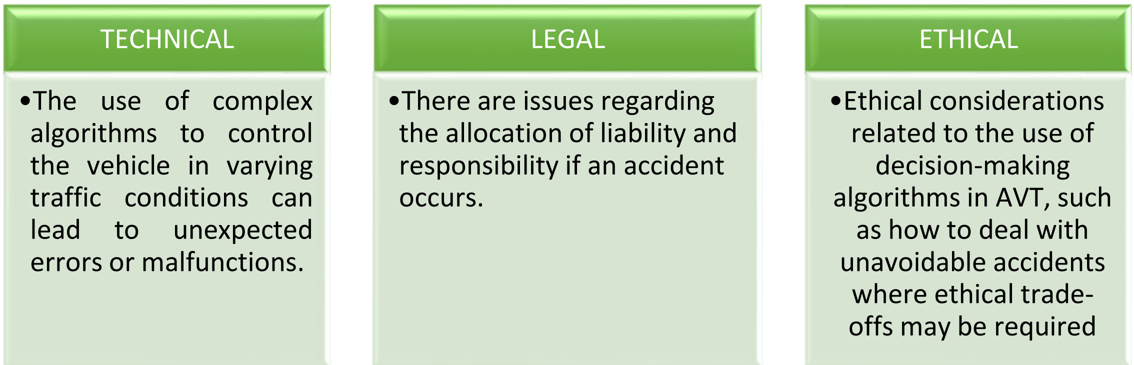


Figure 2-12: Potential risks and challenges of AVT (Ma et al., 2020).

Bernhard et al. (2020) explored the factors that influence the user acceptance of automation vehicles and concluded that the acceptance of automation vehicles is highly dependent on the user's trust in the technology and the user's perception of the technology's safety. It was also revealed that the user’s opinion of the technology is a significant factor in their acceptance of it. The user's acceptance of automated vehicles is also influenced by the user's characteristics, such as age, gender, and level of education. Bernhard et al. (2020) concluded that the user's attitude towards the technology, perceived safety, and trust in the technology are the main factors that influence the user's acceptance of automated vehicles.

Therefore, for automation vehicles to be accepted by users, the technology must be designed in a trustworthy and safe way. It is vital for the user to have a positive attitude toward the technology and to understand the benefits that automation vehicles can provide (Bernhard et al., 2020). A study by Kim et al. (2022) found that trust was the most significant factor influencing user acceptance of automation vehicles, followed by perceived performance and perceived risk. Furthermore, Kim et al. (2022) also explained the importance of providing users with clear and accurate information about the automated vehicle, as this could help increase trust.

2.12. TECHNICAL DEVELOPMENT OF AUTONOMOUS VEHICLES

The development of automation technology in vehicles is an excellent example of the advances in modern engineering. Automation technology has enabled manufacturers to create smaller, more efficient, and safer cars than ever, enabling us to drive with reduced effort and enjoy a more comfortable and efficient ride experience.

Automation vehicles have become increasingly important in technical development, as they can quickly and accurately carry out repetitive tasks that would be too time-consuming for humans to do effectively (Hamburger et al., 2022). Automation vehicles provide the advantages of increased accuracy, increased speed, and lower costs. The advantages of automated vehicles include lower costs, faster speeds, and increased accuracy. They can also perform tasks that are more consistent and accurate than humans. It can contribute to the enhancement of product and process quality. Unfortunately, the automated vehicle industry still faces some challenges. One of these is the high level of accuracy they need to perform appropriately. It can make it harder to maintain and program the vehicles.

Additionally, automated vehicles may be more expensive to purchase and use than manual processes, which can concern companies with tight budgets. Another challenge the automated vehicle industry faces is the potential failure of the machines to achieve the desired outcomes. The necessary safeguards must be in place to ensure they can perform adequately. Despite these challenges, automated vehicles provide many benefits and have become increasingly important in technical development (Hamburger et al., 2022).

Hucko (2017) states three major elements permit autonomous driving: Sensing, Mapping, and Driving policy.

2.12.1. Sensing

One of the most critical factors to consider when developing automated vehicles is creating a 360-degree environment model. It will allow them to identify and map various kinds of objects.

- Sensors: Proprioceptive sensors and Exteroceptive sensors
- Vision-based Cameras
- Radar
- Ultrasonic radar – Sonar

- LiDAR

2.12.2. Mapping

Another essential component that can be considered in developing automated vehicles is the mapping of their environment. They are creating maps designed to help the vehicles navigate the road. The maps used by automated vehicles should continuously be updated to keep up with environmental changes.

2.12.3. Driving Intelligence Policy

The driving Policy is planning for future scenarios.

- Difference between Sensing and Planning
- Reinforcement learning
- Supervised Learning

The development of autonomous vehicles has allowed for a significant increase in safety compared to traditional transportation methods. The study conducted by Milakis et al. (2017) discovered that autonomous vehicles can identify and react to potential hazards with incredible speed and efficiency compared to human drivers, as they can detect objects before they enter their field of view. Furthermore, automated vehicles can maintain a consistent speed and take appropriate action with minimal input from the driver. This leads to decreased collisions, as the driver is not required to react to changing conditions as quickly as a human driver. Automated vehicles can utilize data collected from other vehicles to anticipate better and respond to potential hazards on the road. This allows for a more efficient driving experience and, ultimately, a reduction in collisions caused by human error.

South Africa has been slow to develop a regulatory framework for autonomous vehicles. South Africa is an emerging economy and is not as advanced as other countries such as the US or the UK (Klein, 2019). This lack of development has hindered the growth of autonomous vehicles in South Africa, as the necessary infrastructure and regulations are not in place yet. Klein (2019) suggests that the government must take proactive steps to create a regulatory framework to accommodate autonomous vehicles and ensure their safety. It is also essential to address the legal and ethical implications of introducing such technology.

2.13. Cost Of Implementing Autonomous Vehicles

The cost of autonomous vehicles is a significant concern to the consumer. For these vehicles to be obtained by the public, their cost will have to be reduced. This is only possible when multiple competitors are selling these vehicles (Davidson and Spinoulas, 2015).

The implementation of autonomous vehicles carries significant cost implications for both the private and industrial sectors. These costs encompass a diverse range of factors, including research and development, manufacturing, infrastructure, regulatory compliance, training, and maintenance. The private sector stakeholders, such as individual consumers, bear the costs of purchasing or leasing autonomous vehicles. In contrast, the industrial sector, comprising transportation companies and fleet operators, faces expenses related to integrating technology into their operations and ensuring the necessary infrastructure is in place. Additionally, there are costs associated with upgrading existing infrastructure to support autonomous vehicle capabilities, including the installation of sensors, communication networks, and infrastructure for charging or refueling. Careful consideration of these costs is crucial when evaluating autonomous vehicles' economic viability and sustainability in the private and industrial sectors.

2.13.1. Private sector

Introducing autonomous vehicles in the private sector presents a wide array of advantages, with enhanced safety on the roads being a prominent benefit. By leveraging advanced technologies, autonomous vehicles have the potential to reduce accidents and improve overall road safety significantly. Compared to human drivers, autonomous systems can eliminate the potential for human errors, such as distractions, fatigue, or impaired driving, which are significant contributors to road accidents. This technological innovation promises to create a safer transportation environment for individuals and communities, thereby mitigating the devastating consequences of traffic-related incidents (Pettigrew et al., 2022).

Moreover, autonomous vehicles have the potential to enhance traffic flow and alleviate congestion on our roadways. By leveraging advanced sensors, real-time data analysis, and efficient route planning algorithms, these vehicles can optimize their movements and coordinate with each other, resulting in improved traffic efficiency. With reduced instances of abrupt braking, better lane management, and smoother acceleration patterns, autonomous vehicles can contribute to a more seamless and efficient traffic flow. This not only saves time for individuals but also enhances the overall capacity of road networks, leading to reduced congestion and a more sustainable transportation system (Pettigrew et al., 2022).

According to Pettigrew et al. (2022), autonomous vehicles hold the potential to offer transportation alternatives for individuals who are unable to operate vehicles, such as older people or those with disabilities. This transformative capability can significantly enhance their quality of life by enabling them to retain their independence and access vital services. By providing a reliable means of transportation, autonomous vehicles empower these individuals to engage in daily activities and social interactions, fostering a sense of autonomy and inclusivity within their lives. This remarkable advancement has the potential to bridge accessibility gaps and create a more inclusive society for all.

The implementation of autonomous vehicles in the private sector presents numerous challenges and substantial costs. Adopting this advanced technology requires significant investments in research and development, manufacturing, infrastructure upgrades, and regulatory compliance. Additionally, the integration of autonomous vehicles into existing operations necessitates comprehensive training programs and adjustments to ensure a seamless transition. Moreover, addressing cybersecurity risks and liability concerns associated with autonomous vehicles adds to the challenges private sector entities face. The costs incurred in acquiring autonomous vehicles, maintaining them, and establishing the necessary supporting infrastructure contribute to the financial burden. Thus, while autonomous vehicles offer promising benefits, carefully considering the challenges and costs is crucial for successful implementation in the private sector.

2.13.2. Industrial sector.

Through comprehensive cost analysis and the evaluation of potential savings, autonomous vehicles have the capability to deliver substantial economic benefits. According to Fagnant and Kockelman (2015), the economic impact of autonomous vehicles encompasses various facets, and one significant aspect is the potential reduction in labor costs for transportation companies as a result of diminished reliance on human drivers. By eliminating the need for human operators, these companies can experience substantial savings in terms of wages, benefits, and other associated costs. This shift towards automation holds promising prospects for enhanced economic efficiency and profitability in the transportation industry.

Presently, a considerable portion of transportation expenses is allocated towards compensating human drivers. Nevertheless, the introduction of autonomous vehicles presents an opportunity to curtail this cost significantly, thereby unlocking substantial potential savings for companies operating in the transportation sector. Moreover, the implementation of autonomous vehicles promises to enhance fuel efficiency. Using technologies such as machine learning and real-time data analysis, autonomous vehicles have the capacity to optimize routes, alleviate congestion, and reduce idle time, thereby resulting in enhanced fuel efficiency. This synergy between automation and fuel efficiency has the potential to yield notable economic benefits while also contributing towards a more sustainable transportation ecosystem.

Autonomous vehicles possess the capability to optimize acceleration and speed patterns, which culminates in decreased fuel consumption and emissions. As a direct consequence, this generates savings in fuel costs and contributes to environmental sustainability by reducing the carbon footprint. Additionally, autonomous vehicles hold the potential to increase road capacity and alleviate congestion. Through efficient route planning and coordination, these vehicles can enhance traffic flow, minimize delays, and create a more streamlined transportation system. This enhances the overall efficiency of transportation networks and the overall driving experience for individuals(Fagnant and Kockelman, 2015).

Fagnant and Kockelman (2015) highlight the ability of autonomous vehicles to engage in communication and coordinated movements, leading to notable improvements in traffic flow and reduced travel times. This advancement has the potential to not only save valuable time for individuals but also bring about a reduction in fuel consumption and its associated costs. By leveraging this technology, individuals can expect more efficient and streamlined journeys while contributing to environmental sustainability through reduced fuel usage.

2.14. ENVIRONMENTAL IMPACT OF AUTONOMOUS VEHICLES

Autonomous vehicles have emerged as an up-and-coming solution to tackle the environmental challenges posed by conventional automobiles. With their innovative technologies and capabilities, autonomous vehicles hold the promise of substantially diminishing carbon emissions and mitigating adverse environmental effects. Autonomous vehicles use advanced energy-efficient systems, optimizing traffic flow and promoting intelligent transportation infrastructure. Autonomous vehicles provide a pathway toward a more sustainable and eco-friendly future in the transportation industry. Autonomous vehicles offer significant environmental benefits, including reduced emissions and improved fuel efficiency (Makridis et al., 2018).

The transportation sector is a major contributor to air pollution, releasing significant amounts of greenhouse gases and other pollutants (Crayton and Meier, 2017). However, autonomous vehicles can potentially alleviate these emissions by optimizing driving patterns and reducing congestion through advanced traffic management systems. With the minimization of stop-and-go traffic and optimizing routes, autonomous vehicles can enhance fuel efficiency, reducing energy consumption and lowering emissions. This has the potential to play a pivotal role in combating air pollution and promoting a cleaner and healthier environment (Makridis et al., 2018).

The incorporation of electric and hybrid technologies into autonomous vehicles lays the foundation for enhanced energy efficiency when contrasted with internal combustion engine vehicles (Sciarretta and Vahidi, 2020). This remarkable synergy between autonomous driving and alternative power sources has the potential to make significant contributions to environmental sustainability (Sciarretta and Vahidi, 2020). The incorporation of autonomous vehicles into our transportation system can play a pivotal role in advancing a more environmentally friendly and sustainable future (Sciarretta and Vahidi, 2020). Through the reduction of emissions and improvements in fuel efficiency, the adoption of autonomous vehicles represents a significant stride toward combating climate change and promoting overall environmental well-being.

2.15. CHAPTER SUMMARY

The literature review revealed a complex landscape where autonomous vehicles, often referred to as self-driving cars, were a subject of substantial debate and discussion. One key emerging theme was the numerous challenges associated with introducing autonomous vehicles. These challenges encompassed technological, regulatory, and societal aspects. The intricacies of creating an environment where autonomous vehicles could safely coexist with conventional ones, adapting the existing road infrastructure, and establishing robust safety and cybersecurity protocols were central concerns.

However, among these challenges, the literature also emphasized the potential for autonomous vehicles to revolutionize road safety. Their implementation offered the promise of significantly reducing accidents and fatalities. Through advanced sensors and artificial intelligence, autonomous vehicles could provide higher precision and control, making roads safer for all users. The heightened safety profile was a critical aspect that required exploration within the specific context of KwaZulu-Natal.

Furthermore, the impact of autonomous vehicle implementation extended beyond just safety. It had far-reaching consequences for various stakeholders and included implications for government sectors responsible for regulation, urban planning, and transportation policy. It also encompassed the experiences and perspectives of both users and non-users of autonomous vehicles. Understanding how these technologies might reshape daily commutes, accessibility, and public perceptions was vital in assessing their potential impact on society.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. INTRODUCTION

This chapter outlines the research methodology. In this section, the researcher delves into the intricacies of the research and survey design, emphasizing aspects such as data collection methods and the subsequent data analysis process. Additionally, the chapter explores the validity and reliability of the findings, ethical considerations, and the constraints encountered during data collection.

3.2. AIM

This research study aims to determine the factors influencing the effects of Autonomous Vehicles in the KwaZulu-Natal region. The aim of the research was accomplished through an in-depth analysis of data provided by practicing Civil Engineers within KwaZulu-Natal.

3.3. RESEARCH PHILOSOPHY

The commencement of the research process hinges on the pivotal moment when the researcher must make the critical decision of choosing the right research philosophy. This decision is the foundation for the entire research endeavor, shaping the path for methodologies, approaches, and principles that will steer the investigation (Bell et al., 2022). Research philosophy relates to the evolution and essence of knowledge and represents the researchers' perspective on the world (Saunders et al., 2016). Five major research philosophies serve as fundamental guiding frameworks in research. These philosophies encompass interpretivism, positivism, post-modernism, critical realism, and pragmatism (Saunders et al., 2016). As conceptualized by Saunders et al. (2016) and presented in ***Figure 3-1*** below, the research' onion' visually represents the various layers comprising the research process.

- **Interpretivism**: At its core, interpretivism acknowledges the profound connection between human experiences and the act of imbuing them with meaning and interpretation (Saunders et al., 2016).
- **Positivism**: Positivism adopts a distinctly contrasting perspective, giving prominence to empirical observation and pursuing objective knowledge that can be empirically verified (Saunders et al., 2016).
- **Post-Modernism**: Unlike conventional paradigms, post-modernism confronts the concept of objective truth and overarching narratives. It asserts that reality is fragmented, molded by various viewpoints, and subject to the sway of power dynamics (Saunders et al., 2016).

- **Critical Realism**: Critical realism recognizes the intricate nature of reality, proposing the coexistence of underlying structures alongside observable phenomena (Saunders et al., 2016).
- **Pragmatism**: Pragmatism encapsulates a pragmatic outlook, placing a premium on the effectiveness and usefulness of research (Saunders et al., 2016).

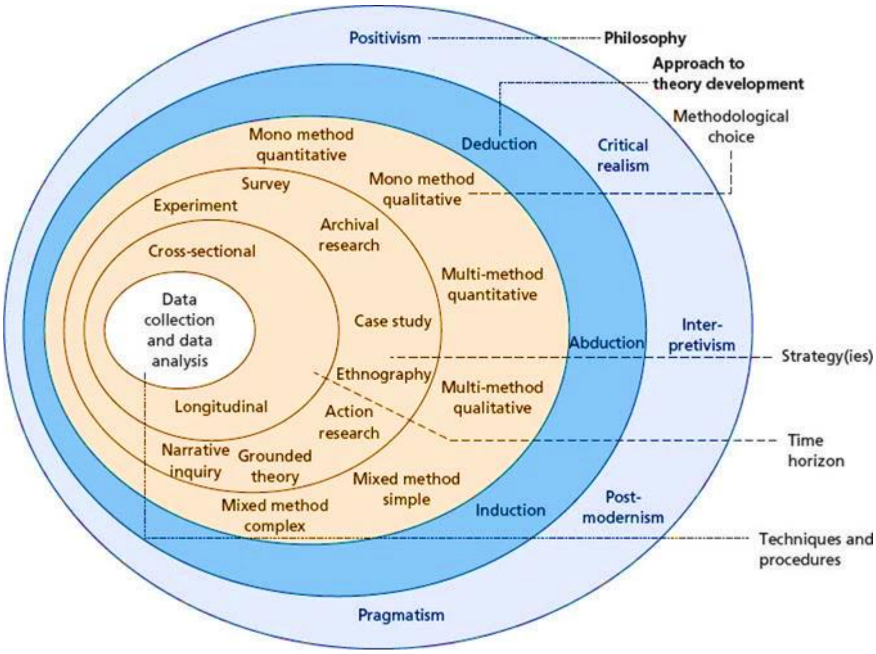


Figure 3-1: The Research Onion (Saunders et al., 2016)

A particular research process predominantly comprises the fundamental elements of research philosophy, approach, strategy, and method used for data collection and analysis (Creswell and Creswell, 2017).

Interpretivism centers on exploring and interpreting human behavior, experiences, and social phenomena within their inherent context (Pham, 2018). Researchers adopting an interpretivist approach frequently employ qualitative research methods for data collection. Qualitative methods, encompassing techniques such as interviews, observations, content analysis, and participant observation, demonstrate an exceptional ability to research the details of human behavior and the social environment (Creswell and Creswell, 2017). These methodologies empower researchers to gather ample, descriptive data showing individuals' or groups' underlying meanings, motivations, and perspectives (Creswell and Creswell, 2017).

The primary objective of this study is to identify the factors influencing the implementation of autonomous vehicles in KwaZulu-Natal and propose recommendations to enhance this implementation. In this study, an interpretive philosophy guides the research approach, employing the inductive method to gain knowledge of autonomous vehicle implementation in KwaZulu-Natal.

3.4. Research Objectives Of The Study

The study's objectives are to identify and comprehensively understand the key factors that influence the successful implementation of autonomous vehicles in the province of KwaZulu-Natal.

- To investigate the efficiency of autonomous vehicles over traditional vehicles.
- To investigate the safety aspect of drivers and vehicles from the advanced technologies of autonomous vehicles.
- To investigate the impact on social issues faced by introducing autonomous vehicles within the South African transport infrastructure.
- Explore the possible financial costs and benefits changes when applying autonomous vehicle technology for everyday use.
- Investigate the challenges encountered by Autonomous vehicles.

3.5. Research Questions Of The Study

The study will discuss the impacts of the technology in terms of the efficiency, safety aspects, social problems, and financial cost implications of introducing autonomous vehicles to the South African road network.

1. What is the efficiency of autonomous vehicles over traditional vehicles?
2. What is the safety aspect of drivers and vehicles from the advanced technologies of autonomous vehicles?
3. What is the impact on social issues faced by introducing autonomous vehicles within the South African transport infrastructure?
4. What are possible financial costs and benefits changes when applying autonomous vehicle technology for everyday use?
5. What are the challenges encountered by autonomous vehicles?

3.6. Participants And Study Location

The study was conducted within the KwaZulu-Natal province of South Africa. The target population for the study was Civil Engineers who practice within the region due to their knowledge and experience in road infrastructure. The participants who agreed to be interviewed were from various companies who are professionals within the field and have previously done projects dealing with road infrastructure.

3.7. RESEARCH DESIGN

The research design is the procedure that translates a research query into a purposeful exploration aimed at addressing the specific research question (Saunders et al., 2016). Research design can be characterized as the structured process involving the collection and analysis of vital data within the predefined framework of the study (Sekaran and Bougie, 2016). This methodical approach extends to the selection of data sources, the choice of research methodology, the timing of data collection, and the tools employed for data analysis (Sekaran and Bougie, 2016). Two commonly utilized research methodologies encompass qualitative and quantitative research (Creswell and Creswell, 2017). The third approach involves the mixed methods research approach, which combines components of both qualitative and quantitative methodologies (Creswell and Creswell, 2017). The mixed-methods approach is based on pragmatism philosophy and shares similarities with the contrast between qualitative and quantitative research (Borrego et al., 2009). The comparison between these two approaches is presented in ***Table 3-1*** below.

Table 3-1: Comparing Quantitative and Qualitative Methods (Techo, 2016).

Dimension	Qualitative	Quantitative
Focus	Quality Or Meaning of Experience	Quantity, Frequency, Magnitude
Philosophical Roots	Constructivism, Interpretivism	Positivism
Goals	Understand, Describe, Discover	Predict, Control, Confirm, Test
Design Characteristics	Flexible, Evolving, Emergent	Structured, Predetermined
Data Collection	Researcher As Instrument	External Instruments
Question Types	Open Ended	Closed Ended

Quantitative research entails gathering data from more prominent and representative samples of respondents to produce numerical data for evaluating the connections between variables (Saunders et al., 2016). This method relies on numerical data to ascertain research outcomes and is particularly suitable when examining closed-ended questions (Creswell and Creswell, 2017). Quantitative research is an indispensable approach when researchers aim to discern and quantify how one variable influences another, often with the deliberate exclusion of the influence of additional variables (Techo, 2016). This method is deeply rooted in positivist philosophy, which emphasizes pursuing empirical, observable, and measurable data. In this light, quantitative research is frequently considered a scientific method, following rigorous procedures to collect, analyze, and interpret numerical data (Creswell and Creswell, 2017). Qualitative research represents an alternative avenue, with its primary goal being the exploration and comprehension of the perspectives, experiences, and intricacies of individuals or groups in relation to a particular human or social issue (Creswell and Creswell, 2017).

3.8. QUALITATIVE RESEARCH

An exploratory research design, more specifically, a qualitative research approach, was used for this study to obtain insight into the factors that potentially impact the implementation of autonomous vehicles from the perspective of civil engineers within KwaZulu-Natal. This research methodology comprehensively examines a research subject without imposing constraints on participant responses and the research's scope. A qualitative research methodology was chosen for this research study, as it was well-suited for exploring the viewpoints and experiences of Civil Engineers in KwaZulu-Natal. Using the qualitative methodology, the researcher can investigate and comprehend how individuals construct meaning in their lives and the significance they attach to their experiences (Merriam and Tisdell, 2015).

Instead of relying on numerical data, qualitative research employs descriptive methods to uncover a more profound comprehension and significance of the phenomena under investigation. The primary objective of qualitative research is to explore, depict, and interpret a situation, utilizing an approach to obtain a broad understanding from participants (Techo, 2016). Researchers utilize open-ended questions to extract comprehensive information from participants, capturing their perspectives and gaining insight into their context.

3.9. SAMPLING METHOD

To address a series of research inquiries, the researcher must undertake the process of sample selection from the population (Taherdoost, 2016). The sampling procedure commences with a precise delineation of the target population and entails the identification of a representative subset of the entire population (Sekaran and Bougie, 2016). Sampling is utilized because it's not feasible to include all population members. Sampling techniques are used to conclude a population and can be categorized into probability and non-probability sampling methods (Taherdoost, 2016). In probability sampling, every individual within the population has an equal and unbiased chance of being selected as a sample. Probability sampling methods encompass stratified, simple random, and cluster sampling techniques. Non-probability sampling techniques encompass elements with no predefined likelihood of selection and include purposive or judgmental, quota, and convenience sampling methods, as illustrated in ***Figure 3-2*** below.

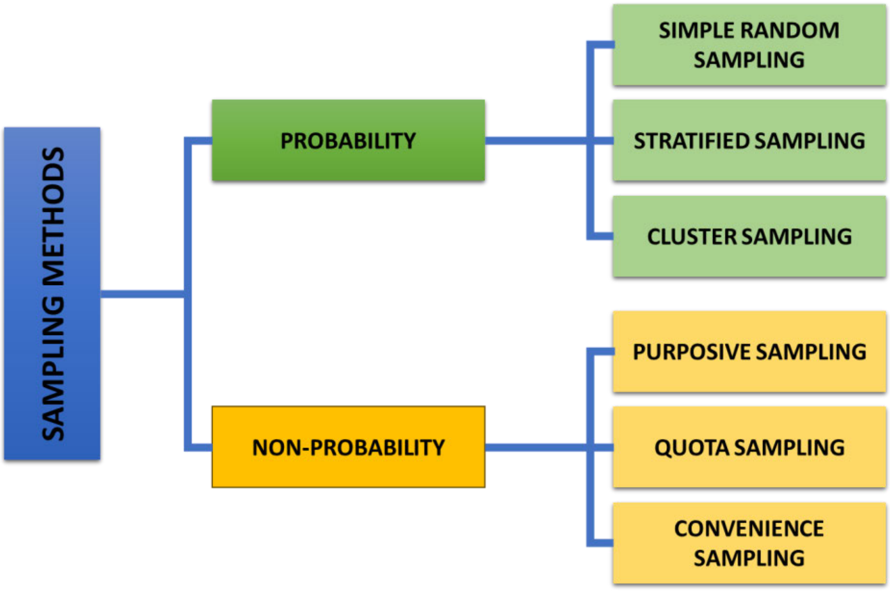


Figure 3-2: Basic Sampling Methods (Sarstedt et al., 2018).

A non-probabilistic sampling approach was opted for this study because it is better suited for qualitative research. In this research, the researcher utilized a purposive sampling method. Purposive sampling entails the deliberate selection of specific individuals to obtain essential information that cannot be obtained through alternative means (Taherdoost, 2016). Purposive sampling facilitates the collection of information-rich responses from participants, drawing on their informal and formal expertise, as well as their perspectives and opinions. The criteria for including participants in this study are also justified by the requirement that they be "Civil Engineers" directly engaged in road infrastructure projects within KwaZulu-Natal. The study's sample size was determined to consist of fifteen (15) Civil Engineers with experience in past or ongoing road infrastructure projects within the region of KwaZulu-Natal. This specific number was chosen to provide a representative group of individuals with substantial knowledge and expertise in the subject matter, ensuring a diverse and comprehensive perspective for the research. The 15 Civil Engineers were purposefully selected, and all participants willingly volunteered to participate in the study.

3.10. Data Collection

In qualitative research, researchers have a range of data collection methods at their disposal, such as visual and textual analysis and interviews with individuals or groups (Gill et al., 2008). Three primary interview types are commonly utilized in qualitative research: unstructured, semi-structured, and structured.

- **Unstructured Interviews:**

  Unstructured interviews are distinguished by their open-ended format, enabling participants to freely articulate their thoughts and experiences (Adams, 2015). They create a forum where respondents can spontaneously and adaptively convey their viewpoints, facilitating a deeper exploration of diverse ideas, emotions, and personal narratives. Unstructured interviews are often compared to informal conversations, and they have the potential to reveal unanticipated insights that might remain hidden in more structured methodologies (Gill et al., 2008).

- **Semi-Structured Interviews:**
  Semi-structured interviews find a balance between flexibility and guidance. Researchers compile open-ended questions or topics to address during the interview, but they also encourage participants to expand upon their responses and offer their insights (Adams, 2015). This method provides a degree of uniformity while permitting the investigation of unforeseen themes and experiences. Semi-structured interviews are frequently chosen when researchers intend to collect extensive information while retaining a measure of organization in the data collection process (Adams, 2015).
- **Structured Interviews:**
  Structured interviews consist of a programmed set of questions, often with standardized phrasing, ensuring uniformity across all interviews (Adams, 2015). These interviews are highly structured, with minimal room for deviation, and are typically used when the researcher aims to gather specific, quantifiable data. Structured interviews are often seen in survey research, where the same questions are asked to many participants, and the data can be easily compared and analyzed (Adams, 2015).

Qualitative research methods significantly enhance our understanding of complex social phenomena by delving into individuals' subjective experiences, perspectives, and interpretations (Gill et al., 2008). Interviews prove particularly effective when a comprehensive understanding is sought from individual participants. In-depth interviews are conducted to encourage extensive information about the perspectives and experiences of respondents regarding a specific subject (Showkat and Parveen, 2017). Participants are encouraged and prompted to share detailed experiences and viewpoints. In this research investigation, in-depth interviews were the primary data collection method. The research explored the factors influencing the implementation of autonomous vehicles in KwaZulu-Natal, which entailed the exploration of individual experiences, viewpoints, and perceptions.

The researcher engaged in both in-person and virtual interviews with participants. These semi-structured interviews comprised a combination of open-ended and closed-ended questions, enabling the collection of opinions and perspectives from the respondents (Creswell and Creswell, 2017).

The interview schedule was designed to aid the researcher in assessing the factors influencing the implementation of autonomous vehicles and formulating recommendations for addressing these factors. Throughout this process, the researcher considered the research questions and the study's primary goals. In designing the interview schedule, the researcher needed to ensure that the questions posed would yield a comprehensive understanding of the phenomenon, aligning with the study's objectives (Gill et al., 2008). During the interview, the researcher adhered to a predefined set of questions to guide the discussion toward meeting the research objectives. Furthermore, additional questions arose naturally as the interviewer and respondent interaction evolved.

The interviews took place from August to November 2020. Civil engineers directly involved in road infrastructure projects were interviewed to ensure a comprehensive information gathering during the process. A candidate list was compiled for interview selection, and these candidates were subsequently contacted by phone to explain the study's purpose and request their participation in an interview. The preparation phase for these interviews proved to be time-consuming for the researcher. Furthermore, alongside obtaining ethical clearance before the interviews, the prevailing COVID-19 regulations posed additional challenges to the process. The researcher conducted six interviews on the engineers' premises, while the remaining nine were conducted via Zoom video conferencing technology.

Each interview had an average duration of 60 minutes. Prior to the interviews, respondents were granted their consent. The researcher documented responses by taking notes during the interviews, which were reviewed and refined while listening to the voice recordings. The in-depth interview empowered respondents to explore issues and offer insights based on their experiences and perspectives. This method enabled the researcher to identify themes that enhanced understanding of how respondents interpreted their environment. Semi-structured interviews can enable the researcher to gather valuable information from participants' experiences, and the predetermined questions help maintain consistency. The interviewer closely monitored the discussion to ensure the interview aligned with the study's objectives.

The researcher collected secondary data from various sources, including journal articles, textbooks, internet resources, media reports, and dissertations.

3.11. DATA ANALYSIS

The data analysis process encompasses the diverse methods through which the researcher interprets the gathered data (Graue, 2015). Qualitative data analysis aligns with the theoretical framework of the research study (Graue, 2015). In qualitative research, data analysis occurs with other study components, such as data collection and the composition of findings (Creswell and

Creswell, 2017). This approach differs from a quantitative study, where the researcher typically follows a sequence of data collection, analysis, and the composition of findings (Creswell and Creswell, 2017). Thematic analysis identified patterns or themes within the data. The researcher used it to gain insight into the factors influencing the implementation of autonomous vehicles by exploring the experiences of diverse respondents.

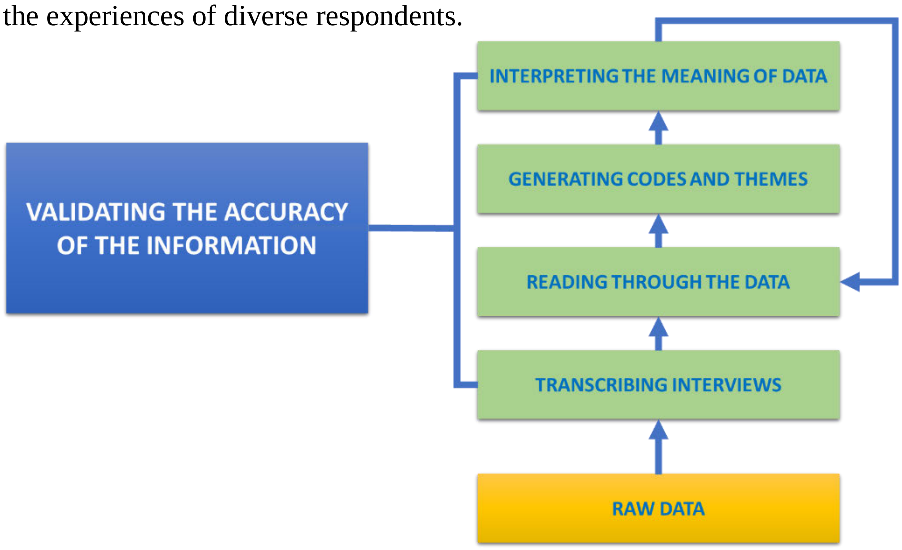


Figure 3-3: Steps in the Qualitative Data Analysis Process (Rezvani et al., 2017).

After each interview, the researcher diligently transcribed and thoroughly analyzed the interview data. Each transcribed interview underwent multiple examinations to identify similarities and differences. The researcher then assigned labels or identifiers to each analysis unit, capturing the underlying significance of the dialogue. This meticulous process involved recognizing recurring patterns and themes. To assist in this effort, a structured system was devised to aid in identifying data patterns. These labels were subsequently organized into categories, providing a framework for interpreting the data's meaning. The process and its outcomes are visually depicted in ***Figure 3-3*** (Creswell and Creswell, 2017).

3.12. Validity and Reliability

The concepts of validity and reliability play crucial roles in the scope of research. Diligence in addressing these aspects can go a long way in establishing the trustworthiness and credibility of research findings. In qualitative studies, where the researcher's subjectivity can potentially influence data interpretation, ensuring validity and reliability becomes even more vital. To assess the validity and reliability of a qualitative research study, the researcher employs a trustworthiness framework that includes considerations of credibility, dependability, transferability, and conformability (Cohen et al., 2017).

Credibility, like internal validity, pertains to the precision, integrity, and suitability of both data sources and their interpretation. The researcher employs credibility measures to strive for results that are truthful but also dependable and trustworthy (Cohen et al., 2017). Creswell and Creswell

(2017) recommend various methods to enhance researchers' capacity to assess the integrity of their findings and persuade readers of their reliability. One such method is member checking, which entails presenting themes or the final report to the research participants, allowing them to evaluate whether they find the findings accurate (Creswell and Creswell, 2017). The researcher used member checking to validate the accuracy of the research findings. The researcher contacted the participants and presented them with the primary themes derived from the interview data. The feedback obtained from the respondents allowed the researcher to determine the accuracy of the results.

Dependability measures help the researcher maintain consistency throughout the data collection, analysis, interpretation, and reporting process, thereby ensuring the accuracy of the results (Awaisu et al., 2019). To achieve this, the researcher systematically organized and stored all collected data on a laptop, facilitating convenient access and efficient data management.

Confirmability pertains to maintaining neutrality in data interpretation. To safeguard the influence of participant responses over the researcher's biases, the researcher diligently monitored their actions and maintained a research journal that documented data-related issues and their evolving viewpoints during data analysis and interpretation.

Like external validity, transferability addresses the broader applicability of research findings (Awaisu et al., 2019).

3.13. Ethical Considerations

The researcher is committed to upholding all research participants' rights, values, and requirements. Numerous ethical measures were taken throughout the study. Ethical approval was obtained from the University of KwaZulu-Natal Research Ethics Committee on August 5, 2020, enabling the researcher to proceed with the study. Additionally, a gatekeeper's letter was provided by the director of the engineering firm, granting the researcher permission to conduct interviews with the firm's civil engineers.

Preserving the anonymity and confidentiality of research participants constitutes a fundamental ethical principle in this study. The researcher assured participants that diligent measures were taken to safeguard their data, preventing any potential traceability to them. The researcher is committed to preventing unauthorized access to the collected information, and all data will be securely stored on a password-protected laptop for five years before being securely disposed of; the data collection process adhered to rigorous ethical standards, with specific steps to protect participants. The interview questions refrained from requesting participants to disclose their names or addresses.

All participation was voluntary, without pressure or coercion on individuals to participate in the study. Every participant received accurate and comprehensive information regarding the research. Notably, the survey did not contain any elements that could potentially endanger or cause physical or emotional harm to the respondents.

3.14. LIMITATIONS TO METHODOLOGY

While valuable insights, the study must be understood within its limitations. It's important to acknowledge that the research did not encompass all civil engineering companies in KwaZulu-Natal and did not extend its scope to major metropolitan areas such as Johannesburg and Cape Town. The exclusion of these areas may have implications for the generalizability of the findings to a broader national context. Limitations of the study include a small sample size due to time and resource constraints, potential bias in data from semi-structured interviews, a regional focus affecting generalizability, potential temporal constraints due to technology's evolution, resource limitations, potential researcher bias, and ethical and privacy concerns impacting data collection. These constraints should be considered when interpreting findings. These limitations might have yielded more insights into the study's objectives. Additionally, due to COVID-19 regulations, some interviews were conducted via video conferencing, leading to technical issues and extended interview durations. Moreover, some respondents opted not to be recorded, extending the interview length.

3.15. CHAPTER SUMMARY

This chapter provides a comprehensive overview of the research methodology, research design, sampling procedures, data collection techniques, and data analysis methods employed in this study. Our primary data collection approach involved conducting semi-structured interviews, and subsequent data analysis was conducted.

Furthermore, careful attention is paid to crucial aspects such as the validity and reliability of the research process, ethical considerations that guided interactions with participants, potential biases that might have influenced the research outcomes, and the limitations inherent in the study's design. These critical elements are thoughtfully addressed to ensure the integrity and accuracy of the research process.

CHAPTER FOUR: PRESENTATION OF RESULTS AND DISCUSSION

4.1. INTRODUCTION

This chapter presents findings and overviews of the primary data derived from interviews. The study was conducted in the KwaZulu-Natal region and specifically targeted Civil engineers specializing in road infrastructure projects. These professionals were actively engaged in road infrastructure projects in KwaZulu-Natal. In total, fifteen (15) civil engineers were interviewed, and this chapter delves into the presentation and discussion of the study's results.

4.2. DEMOGRAPHICS

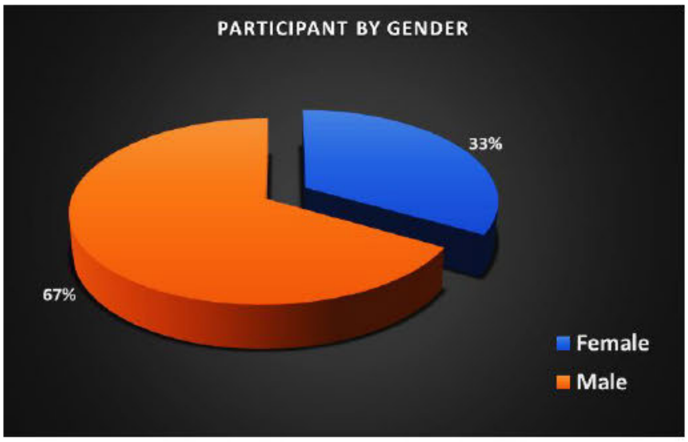
As a result of the implementation of the Protection of Personal Information Act, 2013 (Act No.4 of 2013) on July 1, 2021, companies were restricted from sharing additional information about their employees beyond their academic qualifications. Consequently, the questionnaire contains limited demographic details about the staff members.

4.2.1. Participant Summary

Table 4-1 below displays information about interviewed participants, including their gender, race, age group, possession of a driver's license, and whether they operate a vehicle.

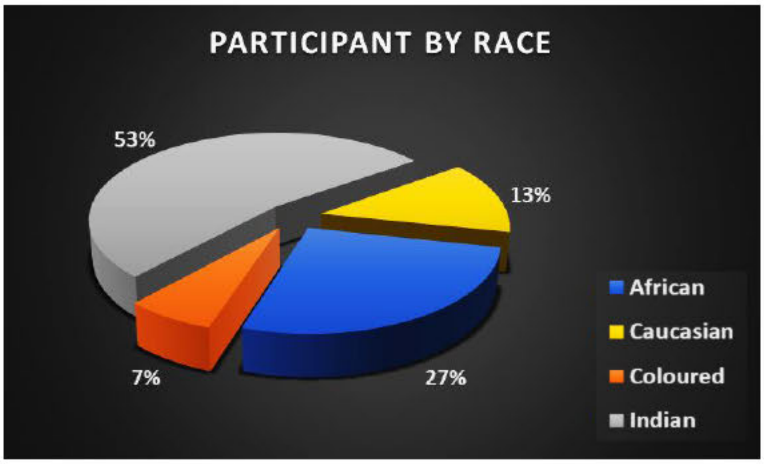
Table 4-1: Participant summary.

Participant	Gender	Race	Age Group	Drives License	Drive A Vehicle
P1	Male	African	30-40	Yes	Yes
P2	Male	African	30-40	Yes	Yes
P3	Female	Indian	30-40	Yes	Yes
P4	Male	Coloured	30-40	Yes	Yes
P5	Male	Indian	30-40	Yes	Yes
P6	Male	African	40-50	Yes	Yes
P7	Female	Indian	30-40	Yes	Yes
P8	Male	Indian	20-30	Yes	Yes
P9	Male	Indian	50-60	Yes	Yes
P10	Male	Indian	30-40	Yes	Yes
P11	Female	Indian	20-30	Yes	Yes
P12	Male	Indian	20-30	Yes	Yes
P13	Female	African	30-40	No	No
P14	Male	Caucasian	40-50	Yes	Yes
P15	Female	Caucasian	30-40	Yes	Yes



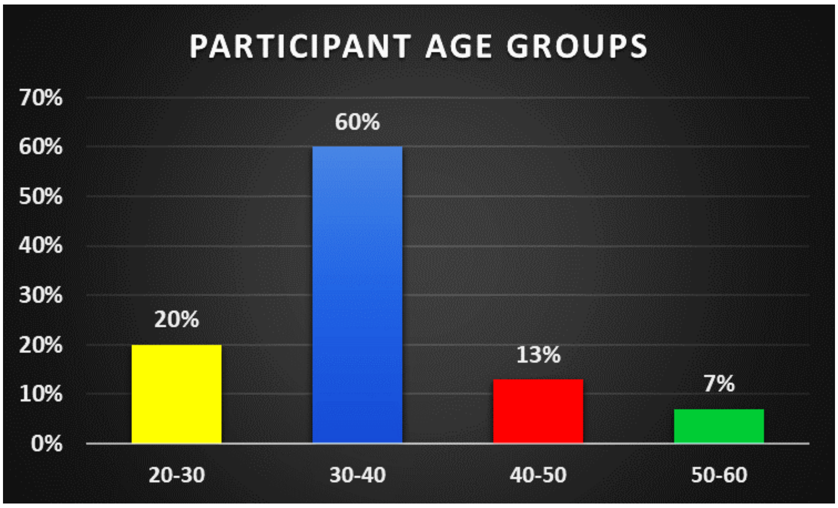
Graph 4-1:PARTICIPANT BY GENDER

Approximately two-thirds, or 67% of the participants, identified as male, while the remaining third, or 33%, identified as female. This gender distribution is visually represented in ***Graph 4-1***, where you can observe the relative proportions of male and female participants in our research (this also shows that Engineering may still be primarily a male dominated field).



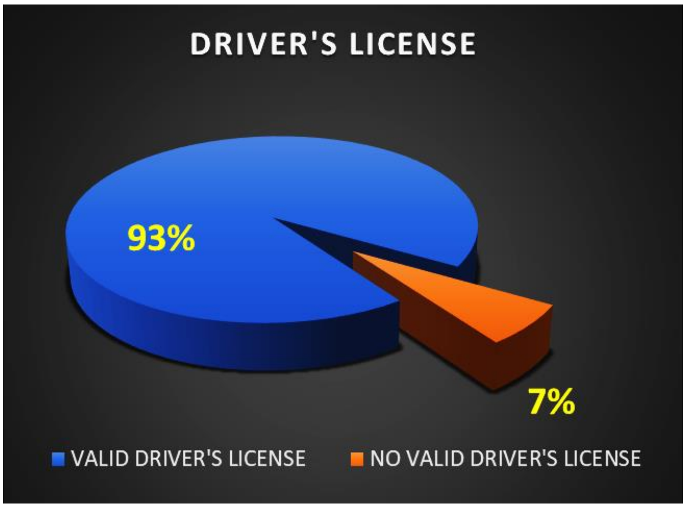
Graph 4-2: PARTICIPANT BY RACE

The distribution of race within our participant group, as depicted in ***Graph 4-2*** above, shows a diverse mix of ethnicities. The breakdown reveals that 53% of the participants identified as of Indian ethnicity. Additionally, 27% of the participants identified as African, 13% Caucasian, and 7% Coloured.



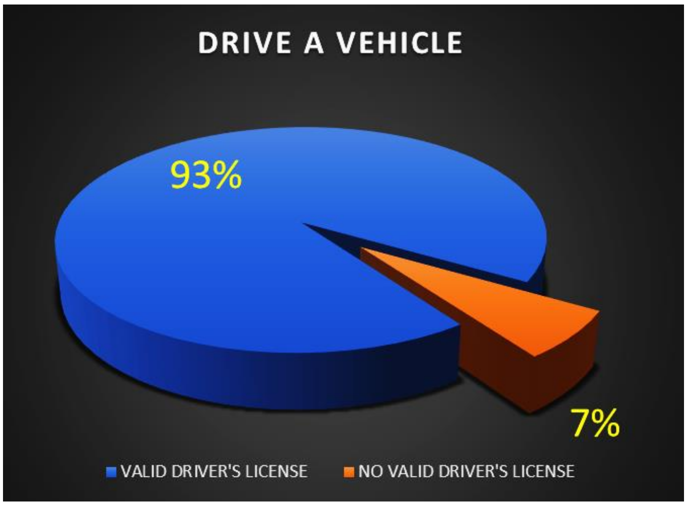
Graph 4-3: PARTICIPANT AGE GROUPS

In terms of age groups, as illustrated above in ***Graph 4-3***, the majority fell within the 30–40-year range, constituting 60% of the participants (this implying high levels of experience and hence are ideal participants for the study). About 20% were in the 20–30-year age group, 13% were in the 40-50-year age group, and a single participant, accounting for 7% of the total, was in the 50-60-year age group.



Graph 4-4: DRIVER'S LICENSE

According to the interview findings, ***Graph 4-4*** presented above showcases the participants' possession of a valid driver's license. A significant majority, 93% of the participants, possessed a valid driver's license. In contrast, a single participant, constituting 7% of the total, did not have a valid driver's license.



Graph 4-5: DRIVE A VEHICLE

In response to whether they operated a vehicle, the data displayed in ***Graph 4-5*** above reveals that 93% of the participants answered affirmatively, signifying that they drove a vehicle. Conversely, a single participant, comprising 7% of the total, indicated that they did not engage in driving a vehicle.

4.2.2. Participant vehicle type

- Passenger Car

  A passenger car, commonly referred to as a car, is a type of motor vehicle primarily designed for the transportation of passengers. These vehicles are designed for personal or small-group travel and are typically not used for transporting goods or cargo (Mehar et al., 2013).

- SUV

  An SUV, or Sport Utility Vehicle, combines the features of a traditional car with those of a larger, off-road vehicle. It typically offers more passenger and cargo space than a regular car and often has elevated ground clearance. SUVs are versatile and popular for family and outdoor activities (Mehar et al., 2013).

- Light Motor Vehicle (Van)

  A Light Motor Vehicle (Van) is a small motor vehicle for transporting passengers or goods. It's larger than a regular car but smaller than a commercial truck. Vans are often used for transporting small groups of people or cargo and come in various sizes and configurations to suit different purposes (Mehar et al., 2013).

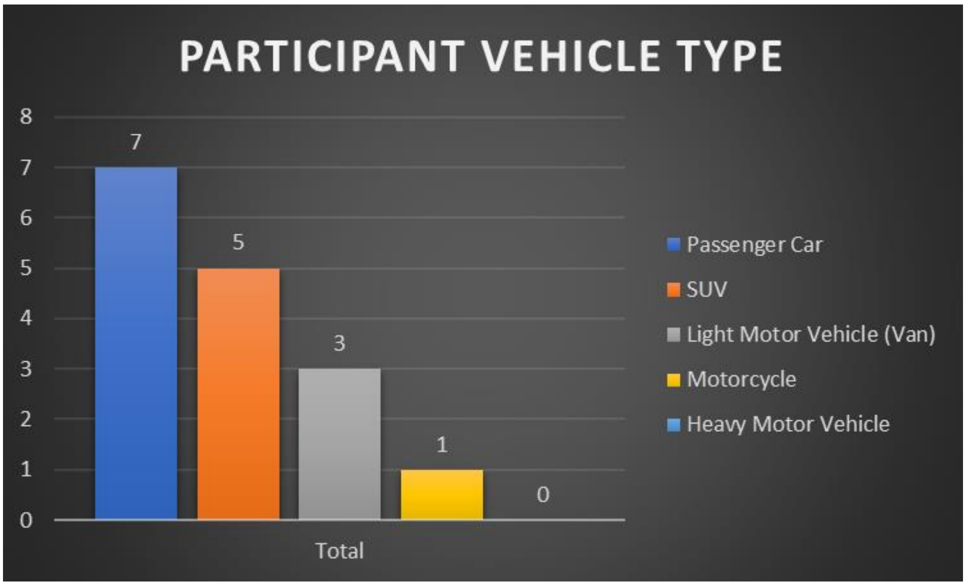
- Motorcycle

  A motorcycle is a two-wheeled motor vehicle typically designed to carry one or two riders. It's smaller, more maneuverable than a car, and powered by an engine. Motorcycles are popular for personal transportation and are known for their agility and speed (Mehar et al., 2013).

- Heavy Motor Vehicle

  A Heavy Motor Vehicle is a large motor vehicle designed for transporting goods or large numbers of passengers. These vehicles include trucks, buses, and other commercial vehicles. They are much larger and heavier than regular cars and are used for various commercial and industrial purposes (Mehar et al., 2013).

According to the interview, participants were inquired about their current vehicle ownership, revealing that the majority (46.67%) possessed passenger cars. SUVs were driven by 33.33% of participants, while light motor vehicles (vans) were the choice for 20% of them. A solitary participant opted for a motorcycle, constituting 6.67%. It is worth noting that none of the participants reported driving heavy motor vehicles. ***Graph 4-6*** below illustrates the result of the findings mentioned above.



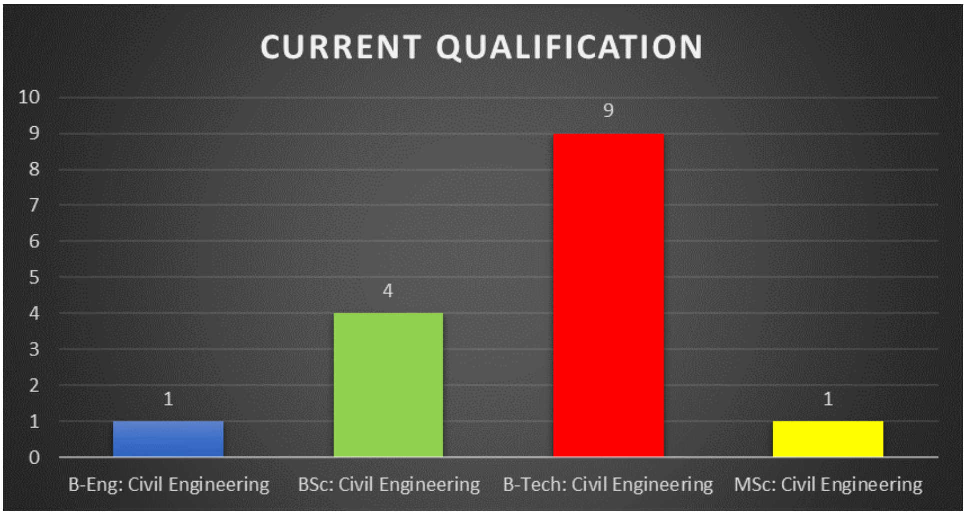
Graph 4-6: PARTICIPANT VEHICLE TYPE

4.2.3. Educational qualifications of participants

Graph 4-7 illustrates a summary of the educational qualifications of the participants. Given the study's emphasis on road infrastructure within the Civil Engineering industry, it was vital to include participants with a strong comprehension of the interview questions. It had experience in road projects, enabling them to make meaningful contributions to the research. The study's participants were drawn from consultant engineers responsible for strategic decisions related to road infrastructure projects. These engineers closely collaborate with key organizations, including the Department of Transport KwaZulu-Natal (DoT-KZN), The South African National Roads Agency Limited (SANRAL), and the eThekwini Municipality.

Most participants, accounting for 60%, hold qualifications in B-Tech Civil Engineering. There is an equal representation of 6.67% for one participant, each with qualifications in MSc Civil

Engineering and B-Eng Civil Engineering. The remaining 26.67% of participants possess qualifications in BSc Civil Engineering.



Graph 4-7: Educational Qualifications of Participants.

The selected participants for this study possessed extensive experience and expertise in the subject matter. Their substantial knowledge and comprehension of South African road infrastructure systems and the methodologies used to enhance efficiency were deemed sufficient for the study's objectives.

4.3. Analysis Of The Data Collected

This section outlines the findings derived from the data corresponding to the interview headings aligned with the study's objectives.

4.3.1. Overview of Headings

An interview schedule was used to ensure that all participants had the opportunity to communicate their perspectives on the same topics. Six headings emerged from the data: *Technological Advancements and Infrastructure, Safety and Regulation, Environmental Impact, Economic Considerations, User Acceptance and Behavior, and Infrastructure Maintenance and Management.* These headings are illustrated in ***Figure 4-1***. The data is subsequently presented and discussed in alignment with the emerging headings.

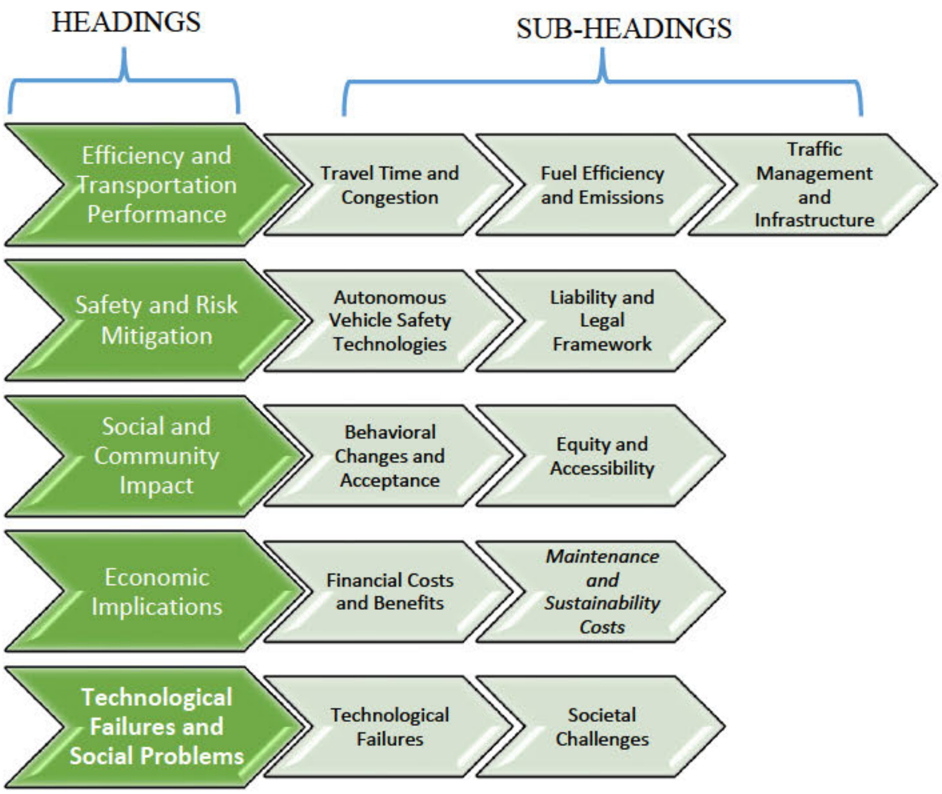


Figure 4-1: Headings arising from interview data.

Heading One, Efficiency and Transportation Performance, emerged from the *study's first objective* and interview schedule. The researcher examines how introducing autonomous vehicles can influence the effectiveness and overall performance of transportation systems in the region. This Heading explores how deploying autonomous vehicles can lead to more efficient and effective transportation, considering various aspects such as travel time, traffic congestion, fuel efficiency and emissions, and traffic management.

Heading Two, Safety and Risk Mitigation emerged from the *study's second objective* and interview schedule. This researcher's heading revolves around understanding how adopting autonomous vehicles can affect safety measures, reduce risks, and enhance overall safety on the road. This heading explores the advanced technologies and safety features integrated into autonomous vehicles and the broader implications for regional driver and passenger safety.

Heading Three, Social and Community Impact, emerged from the *third* objective of the study and interview schedule. In this theme, the researcher focuses on understanding how the introduction of autonomous vehicles affects the social fabric and communities in the region. This heading explores the broader social, cultural, and community changes or challenges of integrating autonomous vehicles into the local transportation infrastructure.

Heading Four, Economic Implications, emerged from the *fourth* objective of the study and interview schedule. In this theme, the researcher centers on understanding how introducing autonomous vehicles can affect the region's economy. This heading explores the financial costs, benefits, and potential changes in the job market and workforce associated with autonomous vehicles.

Heading Five, Technological Failures and Social Problems, emerged from the *fifth* objective of the study and interview schedule. The researcher focuses on exploring the challenges and concerns related to the technology and the societal issues that might arise with the introduction of autonomous vehicles. This heading investigates the potential risks and obstacles that could be encountered as autonomous vehicles become more prevalent in the transportation landscape.

4.3.1.1. Efficiency and Transportation Performance

Table 4-2: Participants suggestion on which is a more efficient type of vehicle between Traditional Vehicles or Autonomous Vehicles.

PARTICIPANT	LIKELY MORE EFFICIENT VEHICLE
P1	Traditional Vehicle
P2	Traditional Vehicle
P3	Autonomous Vehicle
P4	Autonomous Vehicle
P5	Traditional Vehicle
P6	Autonomous Vehicle
P7	Traditional Vehicle
P8	Autonomous Vehicle
P9	Autonomous Vehicle
P10	Autonomous Vehicle
P11	Autonomous Vehicle
P12	Traditional Vehicle
P13	Autonomous Vehicle
P14	Autonomous Vehicle
P15	Autonomous Vehicle

Out of the fifteen (15) participants who participated in the study, ten indicated that autonomous vehicles could be a more efficient mode of transportation based on their knowledge, as illustrated in ***Table 4-2*** above. These participants elaborated on several reasons for this belief, including improved traffic efficiency, reduced fuel consumption, convenience, and enhanced safety.

4.3.1.1.1. Travel time and congestion

Improving travel time and reducing congestion through road infrastructure enhancements is a critical challenge for civil engineers and transportation planners. Strategies to achieve this include expanding road capacity, implementing managed lanes, optimizing intersections, deploying advanced traffic management systems, and promoting active transportation options. These efforts, along with intelligent transportation systems and public transport integration, aim to create efficient and sustainable road networks that benefit commuters and the environment. Collaboration among various stakeholders is essential to achieve these goals and ensure a well-planned and well-maintained transportation system. Participants P4 and P14 shared similar reasoning for their sentiments and stated.

> *"Traffic congestion is a common frustration, and I firmly believe that autonomous vehicles can help alleviate this issue. Their ability to communicate with other vehicles and navigate traffic efficiently can lead to smoother road flow. This saves time and reduces fuel consumption and the overall environmental impact. I see autonomous vehicles as a solution to urban traffic problems."*

According to Ponnan (2015), the swift urbanization and population expansion in the area have generated heightened requirements for transportation infrastructure, causing notable traffic congestion. This congestion not only extends travel durations but also detrimentally affects the overall effectiveness and efficiency of the transportation system.

4.3.1.1.2. Fuel efficiency and emissions

Higher fuel efficiency leads to less fuel consumption and lower emissions. Fuel consumption is significant for mitigating climate change and reducing air pollution. Regulations, technological advances, and consumer choices all contribute to the efforts to enhance fuel efficiency and reduce harmful emissions. These efforts benefit the environment and have economic and corporate social responsibility implications. Participant P4 also went on to explain further about reduced fuel consumption:

> *"One aspect that particularly appeals to me is the potential for autonomous vehicles to be more fuel-efficient. They can be programmed to drive optimally, saving on fuel costs. Given the rising fuel prices and concerns about environmental sustainability, this is a significant factor influencing my preference for autonomous vehicles."*

Autonomous vehicles can optimize driving patterns, minimizing unnecessary acceleration and deceleration, ultimately leading to enhanced fuel efficiency and decreased carbon emissions (Igliński and Babiak, 2017).

4.3.1.1.3. Traffic management and infrastructure.

Traffic management and infrastructure encompasses various aspects of planning, designing, and implementing systems and structures for efficient traffic flow on roadways and transportation networks. Participant P10 stated the following.

"I would suggest autonomous vehicles because of their potential to enhance traffic flow and reduce congestion through real-time communication with other vehicles and traffic infrastructure. Additionally, their integration with public transportation offers seamless and efficient multi-modal commuting, making my daily travel more convenient and timesaving."

Traffic management encompasses a range of extensive strategies, including the optimization of signals, control of lanes, and incident management (Narayanaswami, 2017). These approaches minimize delays, boost road network capacity, and enhance safety. Successful traffic management hinges on a comprehensive grasp of traffic patterns, driver actions, and transportation infrastructure (Narayanaswami, 2017). By deploying intelligent transportation systems (ITS) and advanced traffic control technologies, traffic managers can fine-tune signal timings, coordinate traffic flow, and promptly identify and address incidents as they occur.

According to Djahel et al. (2014), elements like driver behavior, accidents, and road construction can potentially interrupt traffic flow. Therefore, it is imperative to implement effective strategies to mitigate these disruptions and ensure the seamless operation of transportation networks. Adopting advanced technologies and intelligent transportation systems is essential to confront these challenges. These systems can analyze real-time data, fine-tune traffic signal timings, and deliver precise information to drivers, empowering them to make well-informed decisions. By tackling these issues and acknowledging the obstacles in traffic management, transportation authorities can make significant strides towards establishing more efficient and sustainable transportation networks (Djahel et al., 2014).

4.3.1.2. Safety and risk mitigation.

For autonomous vehicles (AVs) and road infrastructure, the central focus revolves around safety and risk management. The critical aspects include setting stringent safety standards, thoroughly testing and validating AVs, fortifying cybersecurity defenses against potential breaches, and incorporating redundancies in sensor systems. Communication between AVs and humans, well-defined emergency response protocols, and safeguarding data privacy are equally pivotal components. Furthermore, road infrastructure adaptation, legal frameworks, public education, and ethical considerations are all fundamental to ensuring the secure integration of AVs into our transportation landscape.

4.3.1.2.1. Autonomous vehicle safety technologies

Prioritizing safety when choosing a vehicle is of paramount importance. Safety considerations extend beyond personal protection, encompassing benefits such as reduced injury and fatality rates, lower insurance costs, peace of mind, better resale value, legal compliance, and a reduced risk of accidents (Wang et al., 2020). Safety features and adherence to standards are essential for individual well-being and contribute to a safer and more responsible transportation ecosystem. For businesses, a commitment to safety can enhance brand image and reputation (Wang et al., 2020). Safety in transportation is a vital component when it comes to choosing a vehicle, and Participant P10 stated that:

> *"One of the main reasons I prefer autonomous vehicles is the level of safety they offer. With their advanced technology, including sensors, cameras, and real-time data processing, they significantly reduce the risk of accidents caused by human errors. These vehicles can make split-second decisions based on vast data, ensuring higher safety for all passengers and other road users. It's comforting to know I'm in a vehicle with such an impressive safety record."*

Participants P1 and P12 have similar sentiments about the safety of traditional vehicles and have stated the following:

Participant P1 stated:

> *"I prefer traditional vehicles because I feel safer in control. I trust my judgment and ability to react to unexpected situations on the road. With traditional vehicles, I know I'm in charge of my safety."*

Participant P12 stated:

> *"I've heard stories of people becoming complacent and over-reliant on autonomous systems. I believe it's safer to stay alert and be in full control while driving a traditional vehicle so I can react when needed."*

4.3.1.2.2. Liability and legal framework

Autonomous vehicles introduce a complex web of legal and liability considerations. As these vehicles operate with varying levels of automation, it's crucial to establish a clear legal framework to determine responsibility in the event of accidents or malfunctions.

Participant P15 stated:

> *"I choose autonomous vehicles because of their advanced safety features. While the liability and legal framework might evolve, enhanced safety measures, such as collision avoidance systems, give me confidence in their ability to prevent accidents."*

Participant P1 stated:

> *"I prefer traditional vehicles because the liability in case of accidents is clear and well-established. We know who's responsible with human drivers, and the legal*

> *process is familiar. Autonomous vehicles introduce uncertainty in determining liability, which makes me uncomfortable."*

Developing a legal framework to promote the safety of autonomous vehicles is a complex and vital undertaking. According to Jensen (2018), the critical points in this process include the need for regulations to oversee the safety of autonomous vehicles, adapting existing traffic laws, addressing product liability, cybersecurity, and ethical dilemmas. International harmonization, testing and certification, data recording and reporting, insurance coverage, and public education are important considerations. Collaboration between government agencies, the automotive industry, and the public is essential to balance innovation and safety in deploying autonomous vehicles on the roads (Jensen, 2018).

4.3.1.3. Social and Community Impact

The introduction of autonomous vehicles holds the potential to bring about profound changes in society and communities. The heading of "Social and Community Impact" in the context of autonomous vehicles encompasses a wide range of effects, including changes in transportation behavior, improved safety, impacts on urban planning and infrastructure, economic implications, environmental benefits, considerations of accessibility and inclusivity, and the importance of public acceptance and trust.

4.3.1.3.1. Behavioral Changes and Acceptance

The acceptance of autonomous vehicles hinges on multiple factors. Building trust in their safety, educating the public about their capabilities, and establishing clear regulations are essential (Jing et al., 2020). A positive user experience, including comfortable interiors and ethical guidelines, can boost acceptance. Autonomous vehicles may change travel behavior, environmental benefits, and economic and social impacts. Overall, acceptance involves not only technological advancements but also changes in societal attitudes and behaviors (Jing et al., 2020).

Participant P9 stated:

> *"I believe autonomous vehicles could significantly impact my daily commute. The convenience and reduced travel time they offer might encourage me to use them more frequently. If they prove reliable and safe, I would be open to adopting autonomous vehicles for my daily transportation needs. It's all about making my commute more efficient."*

4.3.1.3.2. Equity and Accessibility

Ensuring equity and accessibility in developing and deploying autonomous vehicles is essential. This involves making autonomous vehicles affordable, accessible, and accommodating to people with disabilities and elderly individuals (Dianin et al., 2021). Efforts should bridge urban and rural transportation disparities, integrate with public transit, address data privacy concerns, provide job opportunities, engage with affected communities, ensure digital inclusion, and distribute environmental benefits. Equity and accessibility are critical considerations to ensure that autonomous vehicles benefit a wide range of people and do not disproportionately impact vulnerable populations (Dianin et al., 2021).

Participant P10 stated:

> *"Autonomous vehicles have the potential to make transportation more accessible, especially in underserved areas. They can provide on-demand, convenient services to people who may not have easy access to public transportation. This technology can bridge the gap and make it easier for people from various income groups to get around."*

4.3.1.4. Economic Implications

The rise of autonomous vehicles has the potential to revolutionize the transportation sector by lowering expenses and enhancing operational efficiency. According to Williams et al. (2020), autonomous vehicles can employ sophisticated algorithms and real-time data analysis to optimize fuel consumption and mitigate traffic congestion. This optimization can lead to substantial cost savings for transportation firms, reducing fuel expenditures and enabling vehicles to function more effectively. Furthermore, introducing autonomous vehicles can enhance efficiency by minimizing human errors and improving traffic flow. The risk of accidents resulting from factors like driver fatigue, distraction, or errors is significantly diminished by eliminating human drivers. In addition, autonomous vehicles and traffic management systems can communicate with each other to select less congested routes, further boosting overall efficiency. Consequently, the adoption of autonomous vehicles holds the potential to cut transportation expenses and elevate overall efficiency within the transportation industry (Williams et al., 2020)

4.3.1.4.1. Financial Costs and Benefits

One of the key economic benefits of autonomous vehicles, as highlighted by Gružauskas et al. (2018), is the potential for substantial reductions in transportation costs. Autonomous vehicles excel in optimizing routes and minimizing fuel consumption, resulting in significant savings for individuals and businesses. Their integration can increase productivity, as these vehicles operate autonomously 24/7, maximizing their utilization and potentially enhancing overall productivity in the transportation sector. Adopting autonomous vehicles promises to generate job opportunities, offering additional positive economic impacts (Gružauskas et al., 2018). Participant P15 stated:

> *"The financial costs and benefits of AV adoption are complex. On one hand, there's the initial investment in AV technology and infrastructure. It's a significant cost*

balanced by potential benefits like reduced accidents, which could lead to substantial savings in healthcare and insurance expenses. Furthermore, the economic growth from new jobs in the AV industry and enhanced transportation efficiency could benefit our region financially."

4.3.1.4.2. Maintenance and Sustainability Costs

According to Gružauskas et al. (2018), the rise of autonomous vehicles has highlighted the need for robust infrastructure and support systems to ensure smooth operation and maintenance. One of the key challenges in this regard is the development of adequate charging infrastructure for electric autonomous vehicles. Autonomous vehicles' success relies heavily on their ability to recharge efficiently and conveniently. However, like many other regions, KwaZulu-Natal lacks a comprehensive network of charging stations, which can hinder the widespread adoption and use of autonomous vehicles. Additionally, the maintenance and repair of autonomous vehicles pose significant challenges. Given the complexity of the technology involved, specialized technicians and equipment are required for regular maintenance and timely repairs. The scarcity of such resources in KwaZulu-Natal can lead to delays and increased costs in maintaining autonomous vehicles.

> *"Autonomous vehicles are expected to be more reliable and durable, potentially reducing maintenance costs compared to traditional vehicles. However, maintaining their advanced technology, including sensors and software, might be expensive. Nevertheless, lower accident rates and more efficient driving should compensate for these costs in the long run. It's an economic trade-off that we need to study carefully."*

4.3.1.5. Technological Failures and Social Problems

a) Technological Failures:

- **Safety Concerns:** One of the key technological concerns with autonomous vehicles (AVs) is safety. While the technology has come a long way, there's always a possibility of technical failures, whether a sensor malfunction, software glitch, or communication breakdown. Ensuring the safety of passengers and pedestrians is paramount.
- **Cybersecurity Risks:** AVs rely heavily on complex software systems and data connectivity. This introduces the risk of cybersecurity breaches, which could lead to catastrophic failures or malicious attacks on AVs. It's essential to prioritize robust cybersecurity measures to protect against such risks.
- **Technological Dependency:** There's a risk of people becoming overly dependent on autonomous technology as reliance on it increases. In the event of a technological failure, this dependency could lead to confusion and potentially dangerous situations on the road.

b) Social Problems

- **Job Displacement:** The widespread adoption of AVs can potentially displace traditional jobs in the transportation sector, including taxi and truck drivers. This can lead to economic hardships and social challenges as displaced workers seek new employment opportunities.
- **Equity and Accessibility:** AVs might not be equally accessible to all population segments, potentially exacerbating socioeconomic disparities. Ensuring this technology's benefits are accessible to underserved communities is critical.
- **Acceptance and Trust:** People may resist adopting autonomous vehicles due to fear of technology or skepticism about the safety of AVs. Building public trust and acceptance will be a social challenge that needs to be addressed through education and outreach.
- **Legal and Ethical Dilemmas:** AVs can pose unique legal and ethical challenges. For instance, determining liability in case of accidents involving AVs and establishing ethical guidelines for AV decision-making in critical situations are complex issues that society will need to grapple with.

4.3.1.5.1. Technological Failures

Autonomous vehicles utilize advanced technologies such as artificial intelligence, machine learning, and sensor systems to navigate and operate without human intervention. This technology can reduce human errors, accounting for many road accidents (Dixit et al., 2016). Autonomous vehicles can improve road safety by eliminating human factors such as distracted driving, fatigue, and impaired judgment, often associated with accidents (Dixit et al., 2016). Additionally, autonomous vehicles can communicate with each other and the surrounding infrastructure, enabling them to anticipate and react to potential hazards more efficiently. This interconnectedness can lead to a safer and more coordinated transportation system (Dixit et al., 2016).

Participants P11 and P12 have similar statements regarding technology failures in autonomous vehicles:

> *"I have significant concerns about technological failures in autonomous vehicles. While the technology has advanced, it's not infallible. Software glitches, sensor malfunctions, or issues related to communication between vehicles could result in accidents. These failures could lead to a loss of trust in AVs, legal liabilities, and, most importantly, potential harm to passengers and others on the road. Ensuring the safety and reliability of AV technology should be our top priority."*

4.3.1.5.2. Societal Challenges

Addressing technological failures in autonomous vehicles is crucial to maintaining public trust and ensuring widespread adoption of this emerging technology. According to Dimitrakopoulos et al. (2021), the public's perception of autonomous vehicles is heavily influenced by their confidence in the safety and reliability of these systems. Technological failures, such as software glitches or hardware malfunctions, can have severe consequences, including accidents and loss of life, undermining public trust and impeding the adoption of autonomous vehicles. Therefore, manufacturers and policymakers must prioritize identifying and mitigating technological failures to build a robust and trustworthy autonomous vehicle ecosystem (Dimitrakopoulos et al., 2021).

Participant 11 stated the following:

> *"The integration of autonomous vehicles could bring about various societal challenges. One major concern is job displacement in the transportation sector. If AVs become widely adopted, taxi and truck drivers could lose their livelihoods, leading to economic and social hardships. Moreover, introducing new technology may cause discomfort and resistance among some population segments. Addressing these societal challenges will be crucial for a smooth transition."*

4.4. DISCUSSION OF THE STUDY

4.4.1. Efficiency and Transportation Performance.

The study highlights the critical challenge of improving travel time and reducing congestion in road infrastructure. Various strategies are discussed, including expanding road capacity, implementing managed lanes, optimizing intersections, deploying advanced traffic management systems, and promoting active transportation options. Autonomous vehicles are viewed as a potential solution to urban traffic problems due to their ability to communicate, navigate efficiently, and reduce fuel consumption.

The study emphasizes the importance of higher fuel efficiency in mitigating climate change and reducing air pollution. Autonomous vehicles are expected to be more fuel-efficient due to their ability to optimize driving patterns, ultimately reducing fuel costs and the environmental impact.

Effective traffic management and infrastructure optimization are essential to reduce congestion and improve traffic flow. This involves utilizing intelligent transportation systems and advanced traffic control technologies to minimize delays, boost road network capacity, and enhance safety.

4.4.2. Safety and risk mitigation.

Safety is a central concern when it comes to autonomous vehicles. The study highlights the need for robust safety standards, thorough testing, and strong cybersecurity defenses to ensure the secure integration of autonomous vehicles. Given the evolving nature of autonomous vehicle technology, establishing clear liability and legal frameworks is also deemed crucial.

4.4.3. Social and Community Impact.

The study recognizes that introducing autonomous vehicles can lead to profound changes in society and communities, impacting various aspects, including transportation behavior, safety, urban planning, economics, and accessibility. Building trust, public education, and clear regulations are essential for societal acceptance of autonomous vehicles.

The study underscores that the acceptance of autonomous vehicles depends on building trust, public education, and clear regulations. Autonomous vehicles are seen as potentially leading to changes in travel behavior, environmental benefits, and economic and social impacts.

The study emphasizes the importance of ensuring equity and accessibility in developing and deploying autonomous vehicles. This includes making autonomous vehicles affordable, accessible, and accommodating to people with disabilities and elderly individuals. Autonomous vehicles can bridge transportation disparities and provide on-demand services to underserved areas.

4.4.4. Economic Implications.

The rise of autonomous vehicles is expected to revolutionize the transportation sector by lowering expenses and enhancing operational efficiency. Autonomous vehicles can optimize fuel consumption and mitigate traffic congestion, resulting in significant cost savings. They can also increase productivity and job opportunities within the transportation industry.

4.4.5. Technological Failures and Social Problems.

The study discusses the technological failures and social problems associated with autonomous vehicles. Technological failures, such as software glitches and sensor malfunctions, are a concern and impact the safety and trust of autonomous vehicles. Societal challenges include job displacement, equity and accessibility issues, acceptance and trust, and legal and ethical dilemmas.

4.5. CHAPTER SUMMARY

In this chapter, the research findings are presented. The study evaluated the potential impacts of autonomous vehicles on road infrastructure, road users, and non-road users in KwaZulu-Natal. An interview schedule was utilized to collect information from various road infrastructure engineers working in the Civil Engineering industry. Headings were derived from the responses of the participants gathered through the interviews. The results were subjected to a thematic analysis and compared to the existing literature.

Within this chapter, a comprehensive discussion of the study's objectives is conducted based on the perspectives of the participants and the relevant literature on the topic. The subsequent chapter will focus on presenting the conclusions and recommendations derived from this study.

5.1. INTRODUCTION

The study aimed to provide recommendations on the potential impact of autonomous vehicles from the perspective of civil engineers in KwaZulu-Natal. This chapter discusses the conclusion and establishes whether the research problem is resolved. Recommendations are based on the research findings, and finally, recommendations are derived from the current literature evaluation, theoretical underpinnings, and empirical data. All these elements culminate into considerations for future research, drawing the chapter to a close.

5.2. CONCLUSION OF THE STUDY

5.2.1. Objective 1: To investigate the efficiency of autonomous vehicles over traditional vehicles.

The results of this comprehensive investigation leave no room for doubt: autonomous vehicles hold immense potential for revolutionizing transportation efficiency. With their cutting-edge technologies, autonomous vehicles can significantly enhance travel time and alleviate traffic congestion. The study has pinpointed critical factors such as real-time data analysis, optimized route planning, and the mitigation of human error as pivotal contributors to these improvements.

Integrating autonomous vehicles into South Africa's transportation infrastructure promises a brighter future for more efficient and sustainable road networks. This forward-looking approach benefits commuters by reducing travel time and substantially contributes to environmental conservation by curbing fuel consumption and lowering harmful emissions.

5.2.2. Objective 2: To investigate the safety aspect of drivers and vehicles from the advanced technologies of autonomous vehicles.

In the domain of transportation, safety stands as the foremost priority. This investigation underscores that autonomous vehicles introduce a new safety paradigm, setting them apart from their traditional counterparts. The pivotal safety features in autonomous vehicles encompass an array of cutting-edge technologies, including sensors, cameras, and real-time data processing, which significantly reduce the risk of accidents attributable to human error.

Autonomous vehicles have the remarkable capacity to make split-second decisions, informed by an extensive dataset, thereby ensuring an elevated level of safety for both occupants and other road users. Nevertheless, it is imperative to address the concerns revolving around public trust and acceptance, particularly among those who remain skeptical about the safety credentials of autonomous vehicles. Building confidence in these innovative technologies is pivotal for their widespread adoption and realizing their full safety potential.

5.2.3. Objective 3: To investigate the impact on social issues faced by introducing autonomous vehicles within the South African transport infrastructure.

The introduction of autonomous vehicles into South Africa's transportation ecosystem has the potential to guide transformative changes that will reverberate throughout the fabric of society and communities. The anticipated social impacts are wide-ranging and multifaceted, encompassing shifts in transportation behaviors, enhanced safety measures, alterations in urban planning and infrastructure development, economic repercussions, environmental advantages, and considerations of accessibility and inclusivity. Nevertheless, to ensure that these myriad benefits are equitably accessible to all segments of the population without disproportionately affecting vulnerable communities, South Africa must adopt a proactive stance in addressing concerns related to equity, accessibility, public acceptance, and trust.

The impending integration of autonomous vehicles signifies a pivotal moment in the evolution of transportation and its societal consequences. This research aims to elucidate and examine these multifarious implications in detail, shedding light on the opportunities and challenges ahead as South Africa embraces the era of autonomous transportation. Doing so can pave the way for a more inclusive, efficient, and sustainable future for all.

5.2.4. Objective 4: Explore the possible financial costs and benefits changes when applying autonomous vehicle technology for everyday use.

While initial costs are associated with adopting autonomous vehicle technology, such as infrastructure investments, the potential long-term benefits are substantial. These include reduced accidents, enhanced transportation efficiency, and job creation, which could lead to significant savings in healthcare and insurance expenses while fostering overall economic growth.

The potential long-term benefits of this adoption are considerable and diverse, transcending the early expenditures. These benefits encompass a reduction in vehicular accidents and associated costs, an enhancement in transportation efficiency that could mitigate congestion-related economic losses, and job opportunities within the autonomous vehicle sector, with a ripple effect on overall employment and income levels.

5.2.5. Objective 5: Investigate the challenges encountered by Autonomous vehicles.

The study identified key technological concerns with autonomous vehicles, including safety concerns, cybersecurity risks, and the risk of technological dependency. Addressing these challenges is crucial to maintain public trust and ensure the widespread adoption of this emerging technology. Furthermore, social problems such as job displacement, equity, accessibility, public acceptance, and legal and ethical dilemmas require careful consideration and planning as South Africa navigates the introduction of autonomous vehicles.

5.3. IMPLICATIONS OF THE RESEARCH

5.3.1. Efficiency of autonomous vehicles.

A central finding of this study lies in the remarkable potential of autonomous vehicles to enhance transportation efficiency. Advanced technologies, including real-time data analysis and optimized route planning, play pivotal roles in reducing travel times and mitigating traffic congestion. Notably, this translates to streamlined and less time-consuming travel for commuters and significantly contributes to broader environmental conservation efforts by curbing fuel consumption and reducing harmful emissions. Introducing autonomous vehicles into South Africa's transportation infrastructure marks a substantial step towards a more efficient and sustainable road network.

5.3.2. Safety aspects of drivers and vehicles.

Safety in transportation remains a paramount concern, and this research underscores how autonomous vehicles introduce a paradigm shift in this domain. Incorporating advanced technologies, encompassing sensors, cameras, and real-time data processing, can reduce the risk of accidents attributed to human error. These vehicles can make split-second decisions informed by extensive datasets, thereby ensuring a significantly higher level of safety for both vehicle occupants and other road users. Nonetheless, it is essential to address the lingering concerns regarding public trust and acceptance, particularly among individuals who may remain skeptical about the safety credentials of autonomous vehicles. Building confidence in these innovative technologies is pivotal for widespread adoption and realizing their safety potential.

5.3.3. Impact on social issues.

Integrating autonomous vehicles into South Africa's transportation ecosystem carries profound social implications. These impacts are diverse and multifaceted, encompassing shifts in transportation behaviors, heightened safety measures, alterations in urban planning and infrastructure development, economic consequences, environmental advantages, and considerations of accessibility and inclusivity. Nevertheless, to ensure that these myriad benefits are accessible to all population segments without disproportionately affecting vulnerable communities, South Africa must proactively address equity, accessibility, public acceptance, and trust. The impending integration of autonomous vehicles marks a pivotal moment in the evolution of transportation and its societal consequences. This research aims to elucidate and examine these multifarious implications in detail, shedding light on the opportunities and challenges ahead as South Africa embraces the era of autonomous transportation.

5.3.4. The possible financial costs and benefits changes when applying autonomous vehicle technology for everyday use.

Adopting autonomous vehicle technology entails certain initial costs, such as investments in infrastructure and technology. However, the research underscores the substantial long-term benefits that outweigh these initial expenditures. These potential benefits include not only a reduction in vehicular accidents and their associated costs but also an enhancement in transportation efficiency that could mitigate congestion-related economic losses. Furthermore, creating job opportunities within the autonomous vehicle sector, with a ripple effect on overall employment and income levels, represents a considerable economic advantage.

5.3.5. The challenges encountered by Autonomous vehicles.

The study has also identified several key technological concerns associated with autonomous vehicles. These include safety concerns, cybersecurity risks, and the risk of technological dependency. Addressing these challenges is crucial to maintain public trust and ensure the widespread adoption of this emerging technology. In addition to technological concerns, this research has highlighted social problems such as job displacement, equity, accessibility, public acceptance, and legal and ethical dilemmas. These issues require careful consideration and planning as South Africa navigates the introduction of autonomous vehicles.

5.4. LIMITATIONS OF THE STUDY

The study's geographic focus was limited to KwaZulu-Natal, deliberately excluding larger metropolitan areas like Cape Town and Johannesburg. While this selective approach allowed for a more concentrated investigation within KwaZulu-Natal, it also means that the findings should be cautiously applied and not generalized to all provinces in South Africa. The unique infrastructure, demographics, and regional dynamics of different provinces can significantly impact the perspectives and experiences of civil engineers, so it's important to acknowledge the limitations of extrapolating these findings to the entire country.

In terms of methodology, the research adopted a qualitative approach and involved a relatively small sample size of 15 participants. It is crucial to recognize that this sample may not fully represent the diverse spectrum of civil engineers in KwaZulu-Natal. Therefore, the findings should be understood in the context of this limited representation. While qualitative research offers valuable insights into individual experiences and perspectives, it inherently lacks the statistical generalizability associated with larger, more representative samples. This means that the study's conclusions are specific to the participants involved and should not be overextended to the region's broader population of civil engineers.

The quality of the research was intricately linked to the researcher's skills and their inductive orientation as the primary research instrument. Acknowledging that the researcher's background, biases, and subjectivity may have influenced the study's design, data collection, and analysis is essential. To mitigate potential researcher bias, the researcher diligently explored various methods and strategies to enhance the research's quality, such as employing rigorous data collection techniques and well-established research protocols. This acknowledgment underscores the importance of transparency and rigor in maintaining research integrity.

The extensive amount of data collected during the research presented a significant challenge during the analysis and interpretation stages. Managing such a large dataset required a thorough and time-consuming process to ensure comprehensive examination. To address this challenge, the researcher employed a systematic approach, utilizing manual techniques and organizing the data into manageable segments. By adopting structured methodologies and careful documentation, the researcher was able to effectively analyze and interpret the qualitative data.

The study also encountered additional complexities due to the COVID-19 pandemic. Strict safety protocols, including mask-wearing and social distancing, were required to safeguard the health of both the participants and the researcher. While crucial, these safety measures presented practical challenges, particularly face-to-face interviews. The researcher used video conferencing for some interviews to adapt to the new circumstances. This approach allowed for continued data collection while adhering to safety guidelines, highlighting the adaptability and resilience required in research endeavors during unprecedented circumstances.

Several other limitations should be considered:

- Generalizability: The study focuses specifically on the perspective of Civil Engineers in the KwaZulu-Natal region. Therefore, the findings and recommendations may not directly apply to other regions, countries, or contexts.
- Limited Stakeholder Perspectives: Although the study aims to provide insights from a civil engineer's perspective, other stakeholders, such as policymakers, urban planners, and transportation authorities, may also have valuable insights on the potential impact of

autonomous vehicles. The study might not fully capture their perspectives, potentially limiting the comprehensiveness of the findings.

- Future Uncertainty: The field of autonomous vehicles is constantly evolving, and new advancements, regulations, or societal attitudes may emerge after the study is conducted. Therefore, the study's findings might not fully capture the future implications and shifts in the landscape of autonomous vehicles.
- Time Constraints: Conducting a comprehensive study on the potential impact of autonomous vehicles requires sufficient time for data collection, analysis, and interpretation. The study might be limited by time constraints, and some aspects of the topic might not be extensively explored or covered.

5.5. RECOMMENDATIONS FOR FUTURE STUDIES

The study dealt with some factors affecting the introduction of autonomous vehicles in KwaZulu-Natal from a civil engineer's perspective. Recommendations for future studies include:

- Multi-Region Comparative Analysis: Future research could extend its geographic scope to encompass multiple regions within South Africa, including larger metropolitan areas such as Cape Town and Johannesburg. A comparative analysis of different regions would shed light on regional disparities and similarities in the context of autonomous vehicle adoption.
- Quantitative Studies: While this study adopted a qualitative approach, future research could incorporate quantitative methods to provide a more statistically robust perspective. Surveys, questionnaires, and statistical analysis can yield quantifiable data and insights into the prevalence of specific views or challenges.
- Longitudinal Studies: The field of autonomous vehicles is dynamic, and its impact will likely evolve. Longitudinal studies that track changes and developments in KwaZulu-Natal's autonomous vehicle landscape would offer valuable insights into the long-term effects on infrastructure, safety, and society.
- Interdisciplinary Research: Autonomous vehicles have implications that span across various disciplines, including urban planning, economics, and environmental science. Collaborative interdisciplinary studies can provide a more comprehensive understanding of the multifaceted aspects of autonomous vehicle adoption.
- Public Perception and Acceptance: Future research can investigate public perceptions and attitudes towards autonomous vehicles in KwaZulu-Natal. Investigating factors that influence public acceptance and potential strategies for building trust in this technology would be valuable.

- Policy and Regulatory Studies: Autonomous vehicles are subject to evolving legal and regulatory frameworks. Research into the legal and policy dimensions of autonomous vehicle adoption and their practical implications would be instrumental.
- Environmental and Sustainability Studies: Autonomous vehicles have the potential to impact environmental sustainability. Future research could explore the environmental consequences of autonomous vehicles, including energy consumption, emissions, and their overall ecological footprint.
- Technological Advancements: Given the rapid technological evolution in autonomous vehicles, research that continuously monitors and evaluates emerging technologies and their potential impacts would be beneficial.
- Economic Analyses: Expanding on the economic aspects, in-depth studies on the economic implications of autonomous vehicle adoption, including potential cost savings, job creation, and market opportunities, would provide a more comprehensive economic perspective.
- Community Engagement: Engaging with communities in KwaZulu-Natal to understand their specific needs, concerns, and expectations related to autonomous vehicles can be a valuable avenue of research. This would ensure that the introduction of autonomous vehicles aligns with the aspirations and well-being of the local population.

5.6. SUMMARY OF THE CHAPTER

Utilizing a research approach characterized by qualitative and exploratory methods, the study examined the implementation of autonomous vehicles in KwaZulu-Natal, focusing on the perspective of civil engineers. The study aimed to achieve five research objectives related to this topic. The research also provides recommendations based on the key findings to assist policymakers, governments, and road users in understanding the impact of autonomous vehicles on road infrastructure in KwaZulu-Natal and South Africa. The study's findings address the research questions, and this chapter presents potential solutions to address the identified factors. The majority of the literature reviewed aligns with the findings of this research study.

Objective 1: Autonomous vehicles show immense potential to improve transportation efficiency through technologies like real-time data analysis and optimized route planning, benefiting both commuters and the environment in South Africa.

Objective 2: Autonomous vehicles introduce a new safety paradigm with advanced features like sensors and real-time data processing, though addressing public trust remains essential for widespread adoption.

Objective 3: The introduction of autonomous vehicles in South Africa promises transformative societal changes, but equitable access to benefits requires proactive measures addressing concerns of equity and accessibility.

Objective 4: Despite initial costs, adopting autonomous vehicle technology offers substantial long-term benefits, including reduced accidents, enhanced efficiency, and economic growth.

Objective 5: Key technological and social concerns, such as safety risks and job displacement, must be addressed to ensure the widespread adoption and successful integration of autonomous vehicles in South Africa.

The study suggests future research should compare regions in South Africa, use quantitative methods, track long-term impacts, collaborate across disciplines, study public perceptions, examine legal frameworks, assess environmental impacts, monitor technological advancements, analyze economic implications, and engage local communities.

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APPENDIX A- INTRODUCTION FORM AND PARTICIPANTS CONSENT

Informed Consent Letter 3C

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI
Graduate School of Business and Leadership

Dear Respondent,

MBA Research Project
Researcher: Kyle Chetty [redacted]
Supervisor: Prof. B. Z. Chummun 031 260 8943
Research Office: E-mail: RIGEthicsHelp@ukzn.ac.za 031 260 7031

I, Kyle Chetty a MBA student, at the Graduate School of Business and Leadership, of the University of KwaZulu Natal. You are invited to participate in a research project entitled "Investigating the potential impact of autonomous vehicles, a KwaZulu-Natal Civil Engineer's perspective.". The aim of this study is to: Investigate the efficiency of autonomous vehicles over traditional vehicles, investigate the safety aspect of drivers and vehicles from the advanced technologies of autonomous vehicles and investigate the impact on social issues faced by introducing autonomous vehicles within the South African transport infrastructure.

Through your participation I hope to understand the impact of autonomous vehicles on our South African roads. The results of the interview are intended to contribute to dissertation.

Your participation in this project is voluntary. You may refuse to participate or withdraw from the project at any time with no negative consequence. There will be no monetary gain from participating in this interview. Confidentiality and anonymity of records identifying you as a participant will be maintained by the Graduate School of Business and Leadership, UKZN.

If you have any questions or concerns about completing the questionnaire or about participating in this study, you may contact me or my supervisor at the numbers listed above.

Sincerely

Investigator's signature [redacted] Date 29/07/2020

This page is to be retained by participant

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI
Graduate School of Business and Leadership

MBA Research Project
Researcher: Kyle Chetty [redacted]
Supervisor: Prof. B. Z. Chummun 031 260 8943
Research Office: E-mail: RIGEthicsHelp@ukzn.ac.za 031 260 7031

CONSENT

I………………………………………………………………………………(full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

Audio Recording: Yes/No

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

………………………………………… ……………………………
SIGNATURE OF PARTICIPANT DATE

This page is to be retained by researcher

APPENDIX B- INTERVIEW GUIDE

1. What is your Gender?
    - Male ☐
    - Female ☐
2. Race
    - Black African ☐
    - Coloured ☐
    - Indian ☐
    - White ☐
    - Other ☐
3. What is your age Group?
    - 20-30 ☐
    - 30-40 ☐
    - 40-50 ☐
    - 50-60 ☐
    - 60- Above ☐
4. Do you have a driver's license?
    - Yes ☐
    - No ☐
5. Do you drive a vehicle?
    - Yes ☐
    - No ☐
6. What do you prefer to drive?
    - Passenger Car ☐
    - SUV ☐
    - Light Motor Vehicle (Van) ☐
    - Motorcycle ☐
    - Heavy Motor Vehicle ☐
7. What is your current qualification?
8. Which would you suggest being more efficient, autonomous vehicles or traditional vehicles?

9. What do you think South Africa is doing to introduce autonomous vehicles into their road network?
10. What are the disadvantages of introducing autonomous vehicles in South Africa?
11. What would be your biggest concern about introducing autonomous vehicles in the South African road network?
12. When do you foresee autonomous vehicles being introduced in South Africa?
13. How do you rate our South African road Network out of 10, 10 being the highest and 1 being the lowest?

1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

14. Do you think the South African road network will be able to introduce autonomous vehicles into the current network? Explain in terms of the infrastructure.
15. What do you think South Africa is doing to introduce autonomous vehicles into their road network?
16. Do you see a future where autonomous vehicle technology is being introduced in public transportation and how it would affect our current public transportation system?
17. How safe would you feel being in an autonomous vehicle?
18. Do you think autonomous vehicles will help ease the traffic congestion in Cities and other highly congested areas?

YES	NO
☐	☐

19. What are some potential ethical and moral consequences that could arise in the near future as this technology becomes more predominant?

    > *"Traffic congestion accounted for 87 billion dollars in production cost in the United States alone in 2018 (INRIX, 2019)."*

    South Africa is in a similar situation; what is your view on the above statement, and would you say that autonomous vehicles will assist with rectifying this issue?

20. What social impact will be faced by introducing autonomous vehicles within South Africa?
21. How would you say the public road users would respond to autonomous vehicles?

APPENDIX C1- ETHICAL CLEARANCE APPROVAL LETTER

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

05 August 2020

Mr Kyle Chetty (209507080)
Grad School Of Bus &Leadership
Westville Campus

Dear Mr Chetty,

Protocol reference number: HSSREC/00001682/2020
Project title: INVESTIGATING THE POTENTIAL IMPACT OF AUTONOMOUS VEHICLES, A KWAZULU-NATAL CIVIL ENGINEER S PERSPECTIVE.
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 24 July 2020 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 05 August 2021.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

All research conducted during the COVID-19 period must adhere to the national and UKZN guidelines.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Humanities & Social Sciences Research Ethics Committee
UKZN Research Ethics Office Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Tel: +27 31 260 8350 / 4557 / 3587
Website: http://research.ukzn.ac.za/Research-Ethics/

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

INSPIRING GREATNESS

APPENDIX C2- ETHICAL CLEARANCE APPROVAL AMENDMENT LETTER

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

11 July 2023

Kyle Chetty (209507080)
Grad School Of Bus & Leadership
Westville Campus

Dear K Chetty,

Protocol reference number: HSSREC/00001682/2020
Project title: Investigating the potential impact of autonomous vehicles, a KwaZulu-natal civil engineer's perspective.
Degree: Masters

Approval Notification – Amendment Application

This letter serves to notify you that your application and request for an amendment received on 10 July 2023 has now been approved as follows:

- **Change in Supervisor:**
  Current supervisor (Dr Xoliswa Majola)
  New supervisor (Prof BZ Chummun)

Any alterations to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form; Title of the Project, Location of the Study must be reviewed and approved through an amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

HSSREC is registered with the South African National Health Research Ethics Council (REC-040414-040).

Best wishes for the successful completion of your research protocol.

Yours faithfully

[redacted]

....
Professor Dipane Hlalele (Chair)

/dd

Humanities & Social Sciences Research Ethics Committee
UKZN Research Ethics Office Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Tel: +27 31 260 8350 / 4557 / 3587
Website: http://research.ukzn.ac.za/Research-Ethics/

APPENDIX D1- GATEKEEPERS PERMISSION LETTERS: VNA CONSULTING

To: Research Ethics Committee

10th June 2020

University of KwaZulu Natal
University Road
Westville

Private Bag X 54001
Durban
4000

To whom it may concern,

The purpose of this letter is to inform you that VNA Consulting hereby grants permission to Kyle Chetty, student number 209507080, to conduct research titled "INVESTIGATING THE POTENTIAL IMPACT OF AUTONOMOUS VEHICLES, A KWAZULU-NATAL CIVIL ENGINEER'S PERSPECTIVE" by collecting data through an interview process with the Civil Engineers at VNA Consulting.

Your Sincerely,

[redacted]

Preven Naicker
Chief Operations Officer

REALISING
CONTINENTAL
POTENTIAL

CORPORATE OFFICE
596 Peter Mokaba Ridge, Berea, Durban, KwaZulu-Natal, South Africa, 4001
PO Box 70803, Overport, Durban, KwaZulu-Natal, South Africa, 4067

Tel: +27 31 207 8121 I Fax: +27 31 207 8722
Email: info@vnac.co.za I Web: www.vnac.co.za

HEAD OFFICE
10 Kyalami Road, Park 2000 Westmead, Pinetown, KwaZulu-Natal, South Africa, 3610

Tel: +27 31 700 2500 I Fax: +27 31 940 4243

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AUSTRALIA
DENMARK
INDIA
MAURITIUS
SWEDEN

www.vnac.co.za

APPENDIX D2- GATEKEEPERS PERMISSION LETTERS: ARRB SYSTEMS

Park 2000
10 Kyalami Road, Westmead
3610
South Africa
Tel: +27 31 700 2500
Fax: +27 31 940 4243

To: Research Ethics Committee

10th June 2020

University of KwaZulu Natal
University Road
Westville

Private Bag X 54001
Durban
4000

To whom it may concern,

The purpose of this letter is to inform you that ARRB Systems South Africa hereby grants permission to Kyle Chetty, student number 209507080, to conduct research titled "INVESTIGATING THE POTENTIAL IMPACT OF AUTONOMOUS VEHICLES, A KWAZULU-NATAL CIVIL ENGINEER'S PERSPECTIVE" by collecting data through an interview process with the Civil Engineers at ARRB Systems South Africa.

Your Sincerely,

[redacted]

Yeshveer Balaram
General Manager

APPENDIX D3- GATEKEEPERS PERMISSION LETTERS: NAIDU CONSULTING

NAIDU
CONSULTING
ENGINEERING DEVELOPMENT

NAIDU CONSULTING (PTY) LTD
No.5 The Boulevard, West Way Office Park,
7 Harry Gwala Road, Westville, 3635
PO Box 2796, Westville, 3635

T +27 31 265 6007 | F +27 31 265 6011
info@naiduconsulting.com
www.naiduconsulting.com

10 June 2020

To: Research Ethics Committee

University of KwaZulu-Natal
University Road
Westville

Private Bag X 54001
Durban
4000

To Whom It May Concern,

The purpose of this letter is to inform you that Naidu Consulting (Pty) Ltd hereby grants permission to Kyle Chetty, student number 209507080, to conduct research titled "INVESTIGATING THE POTENTIAL IMPACT OF AUTONOMOUS VEHICLES, A KWAZULU-NATAL CIVIL ENGINEER'S PERSPECTIVE" by collecting data through an interview process with Naidu Consulting.

Yours faithfully

[redacted]

J. Padayachee Pr Eng
Director – Bridges & Buildings

APPENDIX E- TURNITIN REPORT

Investigating the Potential Impact of Autonomous Vehicles A KwaZulu-Natal Civil Engineers Perspective_Kyle Chetty_209507080

ORIGINALITY REPORT

7%	7%	2%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

Info ×

Submission Details

Student ID	209507080@stu.ukzn.ac.za
Class Name	BibiC
Class ID	33250414
Submission ID	2240771574
Submission Date	28-Nov-2023 02:56PM (UTC+0200)
Submission Count	1
Grammar marks	N/A
File Name	Civil_Engineers_Perspective_Kyle...
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