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GRADUATE SCHOOL OF BUSINESS
MASTER OF SCIENCE DEGREE IN BUSINESS LEADERSHIP AND CORPORATE
GOVERNANCE**

**A MODEL FOR BLOCK CHAIN TECHNOLOGY SYSTEM TO IMPROVE ROAD
INFRASTRUCTURE: A CASE OF THE DEPARTMENT OF ROADS.**

BY

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APPROVAL FORM

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DECLARATION

I, **Gwete Adam Howard** Student Reg. Number: **B232071B**, do hereby declare that this dissertation is a result of my own investigation and research, except to the extent indicated in the acknowledgments, bibliography, references, and comments included in the body of the report, and that it has not been submitted in part or in full for any other degree to any other university.

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DEDICATION

I would like to dedicate this dissertation to my **Mother** and my dear wife Tabeth and children; Bianca, Prian and Liam for the undying support and unconditional love they offered me all these years in making me the person that I am today. “Thank you Mother for your love and support”.

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ABSTRACT

This study sought to develop a model for the adoption of a block chain technology system to improve road infrastructure. The objective of the study was to harness the benefits of blockchain technology to help overcome the numerous issues encountered during the life cycle of road infrastructure projects. This work focuses on the principles of blockchain technology, the road infrastructure industry, and information exchange. Two studies were carried out that fall within the purview of this research. Focus groups were first utilized to determine where the road infrastructure sector sits in relation to Industry 4.0 and to obtain a deeper understanding of knowing when and how to apply the concepts of blockchain technology to project management in the road infrastructure industry. In order to gain a deeper understanding of the interactions between the road infrastructure and blockchain technology domains, semi-structured interviews were administered to specialists in both fields. Technology enablers and barriers were investigated in order to increase information exchange within the road infrastructure industry, based on the findings of the two studies. The results of the two studies demonstrated a substantial and robust relationship between information sharing, project management in the road infrastructure industry, and the principles of blockchain technology. This research demonstrated the importance of trust in laying the groundwork for effective communication and an accurate exchange of information. In the context of information exchange, it was shown in this research that the concepts of blockchain technology may be applied to road infrastructure projects to improve transparency, traceability, and immutability throughout the entire cycle. The Construction industry has a complex structure with multiple parties involved, which often leads to adversarial relationships, risk avoidance, and a lack of trust among the different actors. This culture is further compounded by a linear workflow that often results in low efficiency, delays, rework and unnecessary waste. Blockchain technology can help to mitigate these issues by creating a decentralised and transparent system, where all the actors can have access to a shared database that allows tracking and monitoring the different stages of the project, and even automate some processes, thereby increasing efficiency and reducing delays and rework. This study highlights the advantages of blockchain technology, particularly how it can provide a single source of truth for project data while allowing multiple parties to access and share data in a secure and transparent way, improving the workflow of projects and decreasing the likelihood of errors, mistakes, or fraudulent activity.

Keywords: blockchain technology; project management; Construction industry; Industry 4.0

Table of Contents

APPROVAL FORM.....	I
RELEASE FORM	II
DEDICATION	IV
LIST OF FIGURES.....	IX
LIST OF TABLES	XI
LIST OF APPENDICES	XII
LIST OF ACRONYMS	XIII
CHAPTER ONE	1
INTRODUCTION	1
1.0 Introduction	1
1.1 Background of the study.....	2
1.2 Statement of the research problem.....	3
1.3 Main aim of the study.....	5
1.4 Research objectives	5
1.5 Research questions.....	6
1.6 Hypothesis (Proposition for qualitative)	6
1.7 Significance of the Study.....	7
1.8 Research assumptions	11
1.9 Delimitations of the Study.....	12
CHAPTER TWO	15
LITERATURE REVIEW	15
2.0 Introduction	15
2.1 Project management.....	16
2.2 Road infrastructure projects	23
2.3 Block chain Technology Overview	37
2.4 The interaction of information exchange and block chain technology	52
2.5 The gap in the literature	60
2.6 Generating a framework for the present research	60
2.8 Chapter summary.....	63
CHAPTER THREE.....	65
RESEARCH METHODOLOGY	65
3.0 Introduction	65
3.1 Research Philosophy.....	66
3.2 Research philosophies	68
3.2.6	72
3.3 Research approaches.....	73
3.4 Research design	75

3.5 Researcher's decision	81
3.6 Research strategy.....	82
3.7 Time horizon	84
3.8 Ethical considerations.....	85
3.9 Chapter summary.....	87
CHAPTER FOUR.....	88
DATA PRESENTATION, ANALYSIS AND INTERPRETATION OF FINDINGS.....	88
4.0 Introduction	88
4.1 Selected research strategy.....	90
4.2 Response rate.....	91
4.3 Background information of respondents: Questionnaires	92
4.4.5 Examining in which aspects of managing road infrastructure projects can the principles of Block chain Technology be effectively utilized in the Department of Roads.	100
4.5.6 To develop a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects.	110
4.6 Presentation of Instruments validity.....	115
4.7 Ethical compliance.....	115
4.8 Chapter Summary.....	116
CHAPTER 5.....	117
SUMMARY CONCLUSION AND RECOMMENDATIONS	117
5.0 Introduction	117
5.1 Summary of the research.....	117
5.2 RECOMMENDATIONS FOR IMPLEMENTATION	122
5.3 Limitations	125
5.4 Recommendation for further study.....	126
5.5 Chapter summary.....	126
REFERENCES.....	127
Section C: Extent of belief that there are interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects.....	148
Section E: Development of a Framework for the Utilization of Block chain Technology in Road Infrastructure Projects.	151
How do you think Block chain technology could improve the management of road infrastructure projects? Justify	151
.....	151
Section 2: Examining in which aspects of managing road infrastructure projects can the principles of Block chain Technology be effectively utilized in the Department of Roads.	155
Section3: Extent of belief that there are interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects.....	155

LIST OF FIGURES

Figure 1: Influencing mechanism of project complexity on project success (based on Ma, 2020).	18
Figure 2: The three dimensions of complexity (adapted from Maylor et al., 2013).....	20
Figure 3: Main phases of an infrastructure project (own presentation based on Spang, 2016)	25
Figure 4: Freeman’s understanding of stakeholder management (Freeman, 1994)	27
Figure 5 The environment of a road infrastructure project and who is affecting the project (Spang, 2016).....	30
Figure 6 The iron triangle (Atkinson, 1999, p. 338).....	34
Figure 7 Number of searches for ‘Block chain Technology’ worldwide, according to Google Trends, 2020	37
Figure 8 Merkle tree of a block chain (Shrier, 2020).....	41
Figure 9 The path of industry 1.0 to industry 4.0 (own representation)	43
Figure 10 Hype cycle for emerging technologies, 2018	45
Figure 11 Centralized system – bank (financial institution)	45
Figure 12 Decentralised system – Blockchain Technology	47
Figure 13 Complex networks	48
Figure 14 Understanding the why of the framework (own representation)	61
Figure 15 Conceptual Framework	63
Figure 16 Research onion (Saunders, 2009).....	66
Figure 17 Deductive research approach	73
Figure 18 Inductive research approach	74
Figure 19 Research choices (Saunders, 2013).....	79
Figure 20.....	84
Figure 21 Gender of the questionnaire respondents (N = 220)	93
Figure 22 Gender of interview respondents (N = 9)	94
Figure 23 Age of the questionnaire respondents (N = 220)	95
Figure 24 Age of interview respondents (N = 9).....	96
Figure 25 Marital Status (N = 240).....	97
Figure 26 Marital status of the interviewees (N = 9)	98

Figure 27 Experience levels of questionnaire respondents with the Department of Roads (N = 240)	99
Figure 28 Experience levels of interview respondents with the Department of Roads (N = 9) ..	100
Figure 30 Research objective 1	119

LIST OF TABLES

Table 1: Road infrastructure accessories (Zander, 2015).....	24
Table 2 Philosophical assumption	72
Table 3 Response rate Source: Primary data (2023).....	91
Table 4 The interviewee profiles (N = 9) Source: Primary data (2024)	92
Table 5 Examining in which aspects of managing road infrastructure projects the principles of Block chain Technology can be effectively utilized in the Department of Roads (N = 220)	101
Table 6 Interviewees' responses on Examining in which aspects of managing road infrastructure projects can the principles of Block chain Technology be effectively utilized in the Department of Roads. (N = 9)	102
Table 7 Exploring the interrelation between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects (N = 220).....	103
Table 8 Interviewees' responses on exploring the extent of interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects (N = 9) Source: Primary data (2024).....	105
Table 9 Assessment of the barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads (N = 220)	107
Table 10 Interviewees' responses on assessing the barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads (N = 9).....	109
Table 11 Need for development of a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads. Table 4. 6: (N = 220)	111
Table 12 Interviewees' responses on developing a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads (N = 9).....	112
Table 13 Survey questionnaire reliability statistics (N=220)	115

LIST OF APPENDICES

APPENDIX	DESCRIPTION	PAGE
Appendix 1:	Interview Guide for Engineers and Senior Managers.....	148
Appendix 2:	Questionnaire for Employees.....	155
Appendix 3:	Research request letter.....	161

LIST OF ACRONYMS

DoR	Department of Roads
EPDs	Environmental Product Declarations
GoZ	Government of Zimbabwe
BT	Block chain Technology
IET	Information Exchange Theory
CSF	Critical Success Factors
KPI	Key Performance Indicators

CHAPTER ONE

INTRODUCTION

1.0 Introduction

The purpose of the research is to develop a model for block chain technology system to improve road infrastructure in Zimbabwe. The research's main focus is to carry out an in-depth case study of the Department of Roads under the Ministry of Transport and Infrastructural Development which has ten provincial offices dotted around the country and its head office at Kaguvi Building in Harare. In this research, the researcher is going to briefly highlight on the background to the study, give a brief statement of the problem, research questions, research objectives, assumptions, delimitations, and limitations, justification of the study and the definition of key terms.

The adoption of block chain technology has recently emerged as a promising solution for promoting sustainable practices in various industries including construction (Risso et al., 2023). The decentralized nature of block chain enables the secure sharing of data among stakeholders, promoting collaboration and facilitating sustainable practices in construction projects (Guan et al., 2023). The environmental impact of traditional economic systems has become increasingly clear, leading to a pressing concern for adopting sustainable practices in the construction industry (Chung et al., 2023; Dal Mas et al., 2022). Past studies have revealed that block chain technology can have positive and negative environmental impacts, depending on how it is implemented (Kopyto et al., 2020; Su et al., 2023).

It is vital to emphasize that the potential applications of Block chain Technology are numerous and directly linked to research advancements. In the future, Block chain Technology will benefit both the construction industry and real estate (Harvest, 2018), allowing the data from environmental product declarations (EPDs) to be more transparent and reliable. Currently, architects, engineers, and real estate developers use EPDs to document building materials (Ershadi et al., 2021). Environmental Product Declarations depend strongly on data monitoring, and Block chain Technology can ensure tamper-proof and scalable recording of all transactions and data. Furthermore, distributed ledger technology offers a viable means of identifying the source of information regarding common legal issues experienced in the construction industry. Thus,

construction delays and legal costs can be minimised, and stakeholders can better understand the construction processes (Shojaei et al., 2021).

1.1 Background of the study

The Zimbabwean government is striving to achieve an upper-middle-income society by 2030, which is a major topic for discussion (GoZ, 2018 and GoZ, 2022). With this in mind, the infrastructure sector is pivotal for economic development, as it directly influences trade, transportation, and overall quality of life. In many countries, road infrastructure is the backbone of this sector, facilitating movement and connectivity. However, the management of road infrastructure projects often encounters significant challenges, including inefficiencies, lack of transparency, and corruption (Zhang et al., 2020).

Road infrastructure is crucial for economic development, as it supports trade, mobility, and access to essential services. Well-maintained roads enhance connectivity between urban and rural areas, promoting inclusive growth and improving the quality of life for citizens. However, many countries face challenges in maintaining and upgrading their road networks, often leading to economic losses and reduced public safety (Zhang et al., 2020).

Historically, road infrastructure projects have been plagued by issues such as budget overruns, delays, and substandard work. These problems are often exacerbated by fragmented information systems that hinder effective communication among stakeholders, including government agencies, contractors, and the public (Dahlberg et al., 2019). The traditional linear project management approaches do not adequately address the complexities and dynamic nature of infrastructure projects, leading to misallocation of resources and public dissatisfaction.

Block chain technology has emerged as a revolutionary tool capable of addressing these challenges. By providing a decentralized, immutable ledger, block chain technology can enhance transparency and accountability in project management. It allows for real-time tracking of project milestones and financial transactions, which can mitigate the risk of corruption and improve stakeholder engagement (Makhdoom et al., 2019). This technology not only offers potential solutions to existing inefficiencies but also enables the development of innovative governance models that foster collaboration among stakeholders (Swan, 2015).

The Department of Roads, responsible for the planning, construction, and maintenance of road infrastructure stands to benefit significantly from the adoption of block chain technology. A pilot

implementation could serve as a case study to evaluate the effectiveness of block chain in improving project outcomes and stakeholder satisfaction. As governments increasingly look to digital solutions to enhance service delivery, the integration of block chain into road infrastructure management represents a timely and necessary evolution in public administration.

Traditional project management methodologies often lead to significant delays and budget overruns. Inefficiencies arise from poor coordination among various stakeholders, including government agencies, contractors, and local communities (Dahlberg et al., 2019). This lack of collaboration can result in duplicated efforts, miscommunication, and wasted resources.

Corruption is a pervasive issue in many infrastructure projects, resulting in the misallocation of funds and substandard work. Lack of transparency in financial transactions and project progress can foster an environment where corrupt practices thrive (Zhang et al., 2020). The absence of a clear, verifiable record of activities further complicates accountability.

Information related to infrastructure projects is often stored in disparate systems, making it difficult to obtain a holistic view of project status and performance. This fragmentation can hinder timely decision-making and complicate the identification of issues that require intervention (Makhdoom et al., 2019).

Block chain's decentralized nature allows all stakeholders to access a single source of truth. This transparency can help reduce corruption by making financial transactions and project milestones verifiable and traceable (Makhdoom et al., 2019).

With block chain, stakeholders can receive real-time updates on project status, enabling quicker responses to issues as they arise. This capability can improve coordination and collaboration among all parties involved (Dahlberg et al., 2019).

The use of smart contracts can automate several processes, such as fund disbursement upon completion of specific milestones. This automation can streamline project management, reduce administrative burdens, and enhance accountability (Swan, 2015).

Implementing block chain can foster a more collaborative governance model, where stakeholders have a say in decision-making processes, thereby enhancing public trust in infrastructure projects (Swan, 2015).

1.2 Statement of the research problem

The Department of Roads in Zimbabwe faces significant challenges in managing road infrastructure due to issues such as lack of transparency, inefficiencies in project tracking, and

difficulties in stakeholder coordination. Traditional systems often suffer from data silos, leading to fragmented information that hampers decision-making (Dahlberg et al., 2019). Corruption and mismanagement in funding allocation can result in project delays and overspending, creating a lack of public trust (Zhang et al., 2020). In Zimbabwe, the past two decades have been marred with economic challenges which led to difficulty in ensuring the continuous rehabilitation and maintenance of road transport infrastructure (AfDB, 2019). The quality of Zimbabwe road infrastructure was ranked by the World Economic Forum at 116 out of 137 in 2018, and this is down from 101. For many years, there has been increased overreliance on road transportation hence accelerated depreciation of the roads, requiring extensive rehabilitation. The condition of roads has deteriorated to the point that Zimbabwe became a bottleneck on the North–South transport corridor, and rural connectivity hardly exists (Pushak and BriceñoGarmendia, 2011). Many user fees have been introduced in Zimbabwe, however with little being seen as coming from the collected funds; administrative fees outweighing construction and maintenance funding. The Department of Roads has limited institutional capacity to undertake its mandate (AfDB, 2019). Problems of under-investment or no investment in infrastructure, and of misconceived, inappropriate or poor-quality infrastructure, are often influenced by geopolitics, national and local politics, and economic and financial interests (United Nations, 2018). Roads in Zimbabwe have been characterized by potholes indicating maintenance gap. The roads are not wide enough with the widening agenda being there for a long time. There is congestion in cities and towns, delaying business, road networks are labelled as poor. New links between towns are yet to be developed. Parking space is in short supply in major towns and cities. Transit cargo is facing delays due to the state of the roads.

Block chain technology presents a promising solution by providing a decentralized, immutable ledger that enhances transparency and accountability in infrastructure projects. By enabling real-time tracking of project milestones and financial transactions, block chain can reduce the opportunities for fraud and ensure that resources are allocated efficiently (Makhdoom et al., 2019). However, the integration of block chain within existing frameworks poses its own set of challenges, including technological barriers, the need for stakeholder buy-in, and regulatory compliance (Swan, 2015).

Despite the potential benefits of emerging technologies, the adoption of innovative solutions in road construction remains limited. Among these technologies, block chain has emerged as a

promising tool that can enhance transparency, accountability, and efficiency in project management. However, the lack of understanding, concerns about implementation costs, and the complexity of integrating block chain into existing systems have impeded its widespread adoption in the construction sector.

The Department of Roads, responsible for planning, construction and maintenance of the national road infrastructure is particularly affected by these challenges. The absence of a cohesive framework for integrating block chain technology into road construction projects prevents the Department from leveraging its full potential to improve operational practices and stakeholder collaboration.

This research aims to address the critical problem of how to effectively integrate block chain technology into road construction processes within the Department of Roads. It seeks to identify the specific challenges faced by the Department, evaluate the potential benefits of block chain, and develop a practical framework for implementation. By doing so, the study will contribute to enhancing infrastructure development practices and promoting the adoption of innovative technologies in the road construction sector.

The road construction sector is plagued by inefficiencies, including poor communication between stakeholders, difficulty in tracking project progress, and a lack of accountability. These issues can lead to increased costs and project delays, undermining the effectiveness of infrastructure development efforts. Block chain technology offers a decentralized, transparent, and tamper-proof solution that could revolutionize project management in road construction.

Thus, this research aims to explore the potential of block chain technology in addressing these problems within the Department of Roads, ultimately improving road infrastructure management and fostering greater public confidence.

1.3 Main aim of the study

1.3.1. To provide a working model for block chain technology system to improve road infrastructure

1.4 Research objectives

- To examine in which aspects of managing road infrastructure projects the principles of Block chain Technology can be effectively utilized.

- To explore the interrelation between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects.
- To appraise the barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects.
- To develop a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects.

1.5 Research questions

The research sought to answer the following questions:

- Which aspects of managing projects the principles of Block chain Technology can be effectively utilized.
- What are the interrelation between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects.
- What are the barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects.
- How to develop a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects.

1.6 Hypothesis (Proposition for qualitative)

This study aims to test the following hypotheses regarding the impact of block chain technology on road infrastructure management within the Department of Roads:

Hypothesis 1: Implementing a block chain-based system will significantly improve the transparency of road infrastructure projects, leading to increased stakeholder trust and accountability.

Hypothesis 2: The use of smart contracts in a block chain model will reduce project delays and cost overruns by automating key processes and ensuring timely execution of contractual obligations.

Hypothesis 3: A block chain system will enhance data integrity and security in road infrastructure management, minimizing the risk of fraud and data tampering.

Hypothesis 4: Real-time data sharing through a block chain platform will foster better collaboration among stakeholders, resulting in improved project outcomes and efficiency.

Hypothesis 5: The adoption of block chain technology will lead to a measurable reduction in administrative costs associated with road infrastructure management compared to traditional methods.

Hypothesis 6: Stakeholder satisfaction with road infrastructure projects will increase as a result of the enhanced accountability and efficiency provided by a block chain-based system.

1.7 Significance of the Study

1.7.1 The Department of Roads

By implementing block chain, the Department can create a transparent system where all stakeholders have access to real-time data on project progress and financial transactions. This transparency can help build public trust and reduce the opportunities for corruption, ensuring that funds are used appropriately.

The automation of processes through smart contracts can streamline administrative tasks, such as fund disbursement and compliance verification. This reduction in bureaucratic delays can lead to faster project completion times and better resource allocation.

Block chain enables continuous tracking of project milestones and expenditures, allowing for prompt identification and resolution of issues. The ability to access up-to-date information can improve decision-making and enhance the Department's responsiveness to challenges.

The decentralized nature of block chain fosters greater collaboration among various stakeholders, including government agencies, contractors, and the public. This collaborative approach can lead to more inclusive decision-making processes and a shared sense of ownership over projects.

Block chain's immutable ledger provides a permanent record of all transactions and project activities. This feature can facilitate audits and evaluations, allowing the Department to demonstrate accountability to the public and other stakeholders. Block chain technology enhances data security through cryptographic techniques, reducing the risks of data tampering or loss. This security is crucial for maintaining the integrity of project information and ensuring that stakeholders can trust the data being shared. Adopting block chain technology positions the Department of Roads as a forward-thinking entity that embraces innovation. This modernization

can enhance its reputation and attract potential partnerships and funding opportunities from both public and private sectors

1.7.2 Government of Zimbabwe and Policy Makers

By enhancing transparency and accountability, block chain can help combat corruption in infrastructure projects, an issue that has historically plagued many sectors in Zimbabwe. With immutable records of all transactions, policymakers can ensure that funds are allocated and spent appropriately, thus fostering public trust in government operations.

Improved road infrastructure is essential for economic growth. By implementing block chain technology, the government can streamline project management, reduce costs, and complete projects more efficiently. This efficiency can attract investments, enhance trade, and ultimately contribute to national economic development.

Block chain allows for real-time data monitoring and reporting, which can improve service delivery in road infrastructure projects. Policymakers can make informed decisions based on accurate data, leading to better maintenance and development of roads that meet the needs of citizens. By embracing block chain technology, the Government of Zimbabwe can position itself as a leader in technological innovation within the region. This shift can encourage further technological adoption across various sectors and attract partnerships with technology firms and international organizations

Block chain's decentralized nature promotes greater stakeholder involvement, including local communities, contractors, and government agencies. Policymakers can leverage this engagement to ensure that infrastructure projects align with community needs and priorities, leading to more sustainable outcomes. The implementation of block chain can provide insights into best practices and innovative governance models, helping policymakers to develop more effective regulations and frameworks that support infrastructure development while ensuring accountability. Given Zimbabwe's economic challenges, an efficient and transparent road infrastructure system can help the government adapt to changing conditions. By ensuring that projects are completed on time and within budget, the government can better allocate resources and respond to crises

1.7.3 Public Sector Employees

Block chain technology fosters a transparent environment where project activities and financial transactions are recorded immutably. This transparency can empower public sector employees to

perform their duties with greater accountability, knowing that their work is subject to scrutiny and that ethical standards are upheld.

The automation of processes through smart contracts can significantly reduce bureaucratic hurdles. Public sector employees can focus more on strategic tasks rather than being bogged down by administrative procedures, resulting in increased job satisfaction and efficiency.

Block chain enables real-time access to project data and status updates. This immediate availability of information allows public sector employees to make informed decisions quickly, leading to more effective project management and timely interventions when issues arise.

Engaging with block chain technology presents an opportunity for public sector employees to enhance their skills in emerging technologies. This professional development can lead to career advancement and a more knowledgeable workforce capable of leveraging technology for improved service delivery.

The decentralized nature of block chain encourages collaboration among various stakeholders, including different government departments, contractors, and the public. Public sector employees can benefit from improved communication and teamwork, fostering a more cohesive work environment.

Public sector employees often serve as liaisons between the government and the public. With block chain facilitating greater stakeholder involvement, employees can engage more effectively with communities, ensuring that public concerns and needs are adequately addressed in infrastructure projects.

As governments increasingly adopt digital solutions, employees who are proficient in block chain technology will be better positioned for job security and relevance in the evolving public sector landscape. This adaptability to technological advancements can enhance their employability and career prospects.

1.7.4 Academia and Researchers

This study enhances the existing body of literature on block chain applications in public administration and infrastructure management. By exploring its specific use in road infrastructure, it provides empirical evidence and theoretical frameworks that can inform future research.

The integration of block chain technology intersects various fields, including computer science, public policy, economics, and engineering. This study can inspire interdisciplinary collaborations,

encouraging researchers from different domains to work together to explore innovative solutions for infrastructure challenges.

By presenting a model for the Department of Roads, the study serves as a practical case that can be referenced by researchers examining the real-world implications of block chain technology. This practical application can help bridge the gap between theory and practice, making findings more relevant to policymakers and practitioners.

Researchers can utilize the findings from this study to inform policy development in infrastructure management. The insights gained can guide policymakers in crafting regulations and frameworks that support the adoption of block chain technology in public sector projects.

The study can prompt discussions about the ethical implications of using block chain in public infrastructure. Researchers can explore issues such as data privacy, security, and the impact of technology on public accountability, contributing to a more comprehensive understanding of block chain's role in society.

The model can serve as a foundation for future studies that investigate other applications of block chain in different sectors, such as healthcare, education, and supply chain management. This could lead to a broader exploration of block chain's transformative potential across various fields.

By highlighting block chain technology as a solution for improving infrastructure management, the study can encourage researchers to investigate other innovative technologies and methodologies that can enhance public sector efficiency and transparency.

1.7.5 Citizens and the general public

By utilizing block chain, citizens can access real-time information regarding the status of road infrastructure projects, including budgets, timelines, and completion reports. This transparency fosters public trust in government operations and ensures that funds are being used effectively.

The immutable nature of block chain records means that all transactions and project milestones are permanently documented. This accountability helps deter corrupt practices and ensures that public officials and contractors are held responsible for their actions, ultimately leading to better service delivery.

With streamlined processes and real-time monitoring enabled by block chain, road projects are likely to be completed on time and within budget. This efficiency can result in higher quality infrastructure, reducing maintenance needs and enhancing public safety. Block chain technology can facilitate more inclusive stakeholder engagement, allowing citizens to participate in decision-

making processes regarding infrastructure projects. This involvement can ensure that community needs and preferences are considered, leading to more relevant and beneficial outcomes.

Real-time data access allows for quicker identification and resolution of problems in road infrastructure projects. Citizens will benefit from timely updates on road conditions, construction delays, and maintenance activities, improving overall public safety and satisfaction.

By reducing inefficiencies and corruption, block chain can lead to cost savings in infrastructure projects. These savings can potentially be redirected to other public services, enhancing the overall welfare of the community.

Access to accurate and timely information empowers citizens to hold their government accountable. Informed citizens can advocate for their needs and priorities, promoting a culture of civic engagement and responsibility.

1.8 Research assumptions

- It is assumed that stakeholders in the road construction sector, including government officials, contractors, and suppliers, are open to adopting new technologies like block chain.
- The research assumes that sufficient and relevant data regarding current road construction practices, challenges, and stakeholder perspectives will be accessible for analysis.
- It is assumed that stakeholders possess a basic understanding of block chain technology, which will facilitate discussions and interviews during the research.
- The assumption is that increased transparency through block chain will lead to measurable improvements in trust and collaboration among project stakeholders.
- It is assumed that the long-term benefits of implementing block chain technology will outweigh the initial costs associated with its adoption.
- It is assumed that the necessary technological infrastructure to support block chain implementation can be established within the Department of Roads.
- The research assumes that existing regulations will allow for the integration of block chain technology into road construction processes without significant legal barriers.
- It is assumed that block chain technology will enhance project management efficiency by providing real-time data access and improved record-keeping practices.

- The research assumes that findings from the case study of the Department of Roads can be applicable and relevant to other similar governmental departments and organizations involved in infrastructure development.

1.9 Delimitations of the Study

Institutional Focus

The study concentrated exclusively on the Department of Roads, excluding other governmental bodies, some private sector participants, and non-governmental organizations involved in infrastructure development.

Geographic Scope

The research was limited to Zimbabwe, examining the specific context, challenges, and opportunities within the country's road infrastructure system under the Department of Roads.

Type of Block chain

The investigation focused on authorised block chain systems that are most applicable to public sector needs.

Time Frame

The analysis considered developments over the past four (4) years from 2020 to 2023, focusing on recent technological advancements and existing practices relevant to road infrastructure.

Data Collection

Data was primarily gathered from secondary sources, including government reports, academic literature, and case studies. Primary data collection will be limited to a small sample of stakeholders, such as departmental senior officials and other technical staff in information technology and road construction.

Regulatory Context

The study assumed a stable regulatory environment for block chain technology in Zimbabwe and will not explore the potential legal or policy barriers that could affect its implementation.

Cost Considerations

While the study assessed cost implications, it did not conduct a comprehensive economic impact analysis across the broader economy or other sectors outside of road infrastructure.

Performance Metrics

The evaluation focused on specific metrics such as transparency, efficiency, and accountability in project management, side lining broader social or environmental impacts.

Technological Focus

The study primarily addressed the technological implementation of block chain without delving deeply into interdisciplinary factors like socio-economic or cultural influences on technology adoption.

1.10 Definition of Key Terms

A **Model** is a simplified representation or abstraction of a system, concept, or phenomenon that is used to understand, analyse, or predict its behaviour and characteristics. Models can take various forms, including mathematical equations, physical prototypes, diagrams, or simulations.

Block chain is a decentralized and distributed digital ledger technology that enables secure, transparent, and tamper-proof recording of transactions across a network of computers. Block chain consists of a series of blocks, each containing a list of transactions, linked in chronological order to form a chain. (Nakamoto, 2008).

A **Technology system** is an integrated framework that combines various technological components, processes, and tools to achieve specific objectives or functions. It encompasses hardware, software, data, and human resources working together to perform tasks, solve problems, or enhance productivity.

Road infrastructure refers to the network of physical facilities and structures that support the transportation of people and goods via roadways. It includes various components designed to ensure safe, efficient, and effective movement.

Information exchange refers to the process of transferring data, knowledge, or understanding between individuals, groups, organizations, or systems. This can occur in various forms, such as verbal communication, written documentation, digital transmission, or through automated systems.

1.11. Summary of the chapter

In the introduction to the research chapter the context of the research is presented. This chapter provides a collocation of the problems of poor performance in road infrastructure project

management and an explanation of what the Block chain Technology is and at the same time why this technology might help in the field of road infrastructure project management. The development of the industrial revolution was explained and that it is necessary to observe whether the advantages of the Block chain Technology can support in solving the known challenges in the road infrastructure. Based on these considerations the research question was developed. In order that the research question can be answered, the research objectives were generated. With research objectives and the aim, it will be investigated how the principles of the Block chain Technology support the management of road infrastructure project management.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

In the following chapter, the literature review and thus the basis of the research will be discussed. At the end of the chapter, the researcher will have a wide understanding of the current stage of knowledge, in themes like project management, road infrastructure projects, Block chain Technology and information exchange, which is relevant and the foundation to this research. Basically, the literature review will identify the gaps at this point in time to be able to link up to further research. The first part of the chapter identifies the themes of project management and road infrastructure projects. Project management is getting such an important focus, because the construction of roads, such as planning and building, has been carried out in the form of projects since time immemorial (Spang, 2016). Based on experiences, the perception is developing more and more that a production process and holistic project success related to the end product is only possible with a holistic view and treatment of the project, from the idea to the use. Road construction projects are usually not only of considerable financial proportions, but also of considerable magnitude in terms of the area affected and the people and organizations involved (Hertogh et al., 2008). In correlation with road infrastructure projects, complex projects are also discussed. The understanding of complexity entails different areas, such as different stakeholder expectations, complexity regarding cultural complexity, socio-political complexity and emergent complexity. This is only one of the reasons why road infrastructure projects can be defined as complex projects. The meaning of complexity will be explained in one of the following sub-chapters in more detail. Secondly, Block chain Technology will be introduced and critically reviewed. As road infrastructure projects involve a lot of different stakeholders, trust, transparency, traceability and information exchange are big themes in this area. As Block chain Technology is known to be used in areas in which trust is an issue, this technology is chosen for the present research (Lemieux, 2016). The third section represents the aspects of the information exchange management and the decision-making methods. Spang (2016) argues that the communication between the different stakeholder in road infrastructure projects is an important parameter. Accordingly, a literature review in the field of information exchange is conducted.

Finally, the need for these different topics in this research will be highlighted and they will be brought together in a coherent manner.

2.1 Project management

2.1.1 Definition of the term project.

Prior to elaborating on the term project management, the term ‘project’ will be defined and how projects come about will be analyzed. The Project Management Institute (PMI) divides a project into two key characteristics:

“A project is temporary and undertaken to create a product,” (PMI, 2017, p.4). The given definition is explained by PMI (2017) as the following, a project is a service or a result that is unique. Projects are executed to achieve objectives through the production of deliverables. An objective is defined as the result towards which the work is directed, a strategic position that is achieved, a purpose that is fulfilled, a result that is achieved, a product that is produced or a service that is provided. A deliverable is defined as a distinct and verifiable product, result or capability that must be produced or provided in order to complete a process, phase or project. Deliverables can be tangible or intangible.

2.1.2 Complexity in projects

Complexity in project management starts with the construction project team. The project team can differ in every project. The only reason why a project team is set up, is because of the development of the construction, a building or a road for example. According to Cherns and Bryant (1984), the project team or the different stakeholders differ on the one hand in their different roles and positions and on the other hand also in their belonging to different organizations. The key parameters for a complex project setting are the quantity of custom made components, the sub-components of a system and a big part is the degree of technological novelty (Hobday, 1998). Hence, many large construction projects, such as road infrastructure projects, are categorized as complex products and systems. For this reason, Geraldi et al. (2011) suggested classifying these types of large projects as complex projects. Complexity is supported by five dimensions, structural complexity, uncertainty, dynamic, pace and socio-political complexity. The different parameters of complexity will be explained in more detail later in the chapter.

From the perspective of Engwall (2003), the whole environment of a project can be called complex. This is explained as a project environment is a crucial factor that can influence behaviors,

knowledge and even the project goal. This is related to the pre-project, to past experiences, disruptive events during the life cycle phase, and values during the whole organization and vision of a project, after it is completed.

As was defined at the beginning of the sub-chapter, the organization of large projects or mega projects, such as road infrastructure projects, is a complex construct, as the number of stakeholders is growing and the distribution of their tasks has become more complex (Spang, 2016). Given these themes, it is clear that the term complexity is becoming an increasingly important factor regarding the challenges within such project environments.

McIntosh (2013) explained that complexity means, that a lot of different components are involved and it is hard to recognize all the parameters that influence the outcome or to find good solutions for the challenges that are arising together with the complexity along the whole life cycle of a project. When it is spoken about different components all different kinds of challenges that can occur within the scope of the project environment are meant which means for example, social complexity, environmental complexity or also factors like the socio-political environment. Atkinson (1999) explored how to improve the efficiency of project management, looking at the impact of complexity in mega construction project success. In this study, a relationship was demonstrated between project complexity and project success in mega construction projects. The understanding of project success will be explained in more detail. From a general understanding, the meaning of a successful project is one that is completed on time, on budget and to the required quality.

To get a better understanding of complexity in mega projects, this complexity is merged into five aspects in the Chinese paper; the technological complexity (TC), organizational complexity (OC), goal complexity (GC), environmental complexity (EC) and cultural complexity (CC). Regarding project success, the five dimensions are: schedule (SC), cost (CO), quality (QU), stakeholder satisfaction (SS) and sustainability (SU). The following example refers to the study of Ma conducted in 2020. The following figure reveals the influencing mechanism of project

complexity on project success.

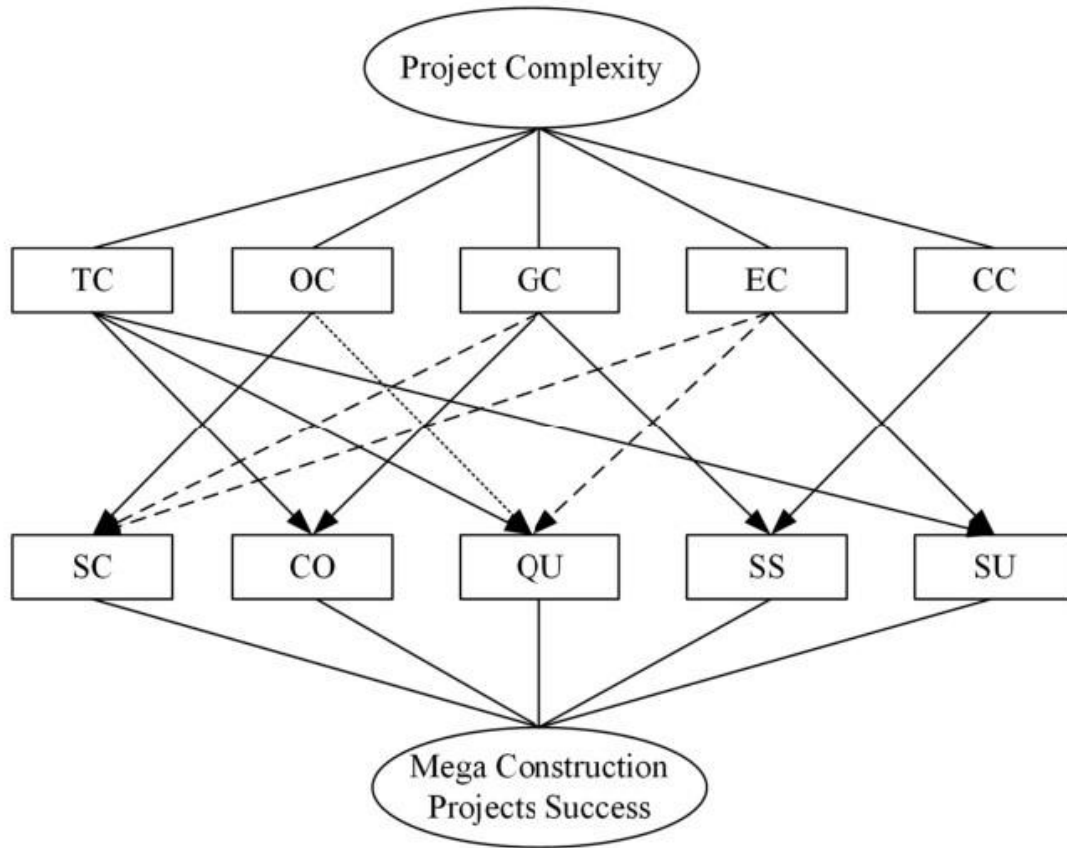


Figure 1: Influencing mechanism of project complexity on project success (based on Ma, 2020).

In principle, the study confirmed that a high Technology Complex, Goal Complex, Environmental Complex or Cultural Complex has a negative effect on variable dimensions of project success. It is obvious that a distinct low or high Organizational Complex negatively affects the construction of a project.

The result of the study presented that a project has serious delays if the Organizational Complex factor is high or there is a combination of a high Environmental Complex and Goal Complex. This is a reasonable result, as the construction of mega projects needs the attendance of different organizations that have to participate with each other and a permanent information exchange with each other is required (Senescu et al., 2012). As the construction of a road infrastructure project takes longer and is more complex than a common project, a higher uncertainty from the environment perspective is also expected (Jia et al., 2011). Having a look at the parameter cost (CO), the two parameters technological complexity and goal complexity influence it. This relates

to the fact that, in a road infrastructure project, the participants need to manage a lot of unpredictable risks. In order to achieve the project goals, the participants need to communicate at the same time with partners (Ma, 2020). On the other hand, it needs to be considered that, in every road infrastructure project, scores of unique and complex technologies are required. The procurement of these technologies normally takes more time than planned (Puddicombe, 2012). Wu et al. (2017) found that a high goal complexity also results in costs overrunning.

Ma (2020) found that the quality of a project is affected by high technological complexity or a combination of high environmental complexity and low organizational complexity. In a study in 2013, it was found that it is possible that errors in a road infrastructure project occur because of the multiple and complex technologies that need to be used (Fast- Berglund et al., 2013). In terms of the Environmental Complex and Organizational Complex, it needs to be understood that the implementation of a road infrastructure project is influenced by the project's natural environment. With the help of the organizational complexity, this environment can be managed. This leads to the fact that the cooperation of many organizations is able to reduce the effects of environmental factors. Thus, it is obvious that the quality of a road infrastructure project is affected even if only a small group of the organizational level is included in the vast environmental challenges (Luo et al., 2017).

The stakeholder satisfaction is affected by goal complexity and cultural complexity. The diversity of the goals of a project affects the implementation of the project in all its different phases that can be directly related to the key stakeholders. On the other hand, organizations from all over the world, with different cultural understandings, are involved in such projects, which makes the cooperation and conversations more difficult. These parameters lead to the fact that the stakeholder satisfaction is affected (Luo et al., 2017).

Lastly, sustainability needs to be considered. Ma (2020) found that sustainability is affected by technological complexity and environmental complexity. This can be explained easily, with the above statements, that a high Technology Complex can affect the quality of a project. It is obvious that changes in the environment influence the sustainability (Agostini et al., 2017).

Finally, Ma (2020) stated that although a mega construction project operates continuously and maintains its functional stability in a period of time, the rapid social and economic development setup may not fully meet the new needs of the people and lead to reduction in its sustainability

performance evaluation, which is an essential factor that should be considered when designing a mega construction project in the early stage.

As introduced at the beginning of this section on complexity, a paper by Geraldi et al. (2011) provides an overview about complexity in the field of project management. According to this paper, complexity is split into five different types: structural complexity, uncertainty, dynamic complexity, pace complexity and socio-political complexity. As complexity was developed further over the next couple of years, Maylor et al. (2013) provided further detail of the five types. Here, the structural complexity and socio-political complexity is highlighted and a third dimension is added to them, emergent complexity. This in turn is split into uncertainty and change, as shown in Figure 2.

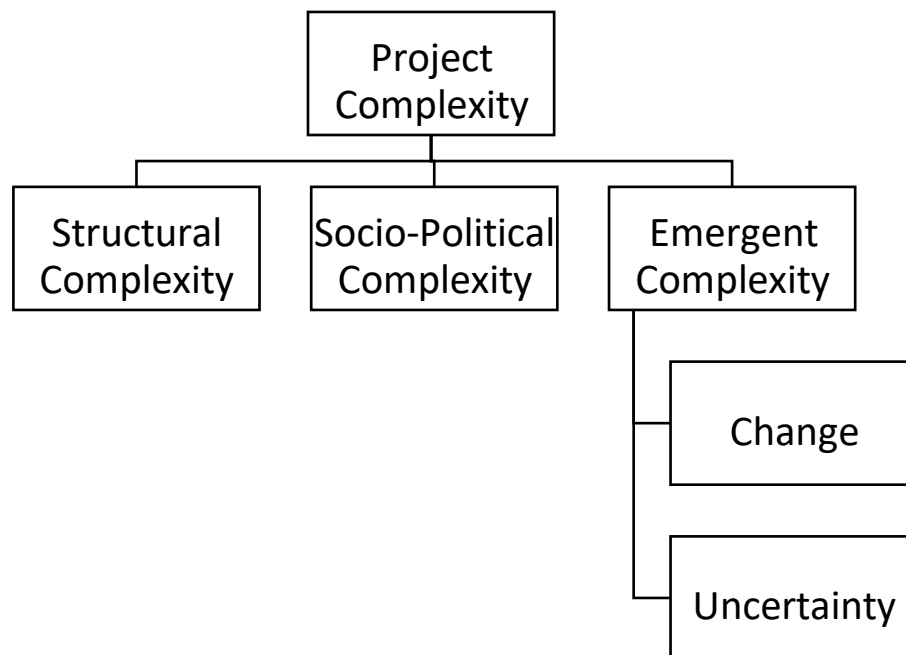


Figure 2: The three dimensions of complexity (adapted from Maylor et al., 2013)

In reference to the above figure, the meaning of structural complexity means the complicated tasks which are faced in a road infrastructure project. The socio-political complexity is related to the large number of stakeholders and external parties in road infrastructure projects (Maylor et al., 2013). The area of emergent complexity is focusing on the core of the topic complexity, which is uncertainty. As Maylor et al. (2013) mentioned, uncertainty is one of the core problems of complexity in road infrastructure projects. Change, which includes modifications to stakeholder

groups, technology, and organizations, represents the second degree of emergent complexity. In the realm of socio-political complexity, it is well-known that institutions and stakeholders are isolated from one another, despite the necessity of their connection. There are various stakeholders involved behind each of these variously termed aspects.

There are other sub-factors as well, which are called community tolerance, political administration and institutional response. Gharehbaghi (2019) proved that, if all authorities are involved to the same degree, projects are more manageable. As Gharehbaghi (2019) demonstrated with regard to mega rail projects, the known complexity is based on future challenges and not in balancing the sustainable factors. In projects there are three sustainable factors namely environmental, economic and social factors. A fourth factor was added here, which is the engineering one. The advantage of adding an engineering factor is that uncertainties and predicaments can be managed better (Gharehbaghi, 2019).

Various factors, such as numerous stakeholders, for example the public, the politicians, the building owner and the different construction organizations (Spang, 2016), complex engineering and changing environmental factors, are responsible for the challenge of managing complex projects such as road infrastructure projects. The environmental factors are affected by parameters like nature protection, bird sanctuary or historic monuments, for example. Natural disasters that cannot be planned must be taken into account as well. In every project, the management function interacts with and exhibits a level of dependency (Bible and Bivins, 2019). Flyvbjerg (2007) stated that major projects are congenitally risky due to the long execution timelines and a complex interface between project participants during the different phases. A road infrastructure project lasts around 30 years, which means that a lot of different generations and cultures are involved (Spang, 2016).

2.1.3 Uncertainty of complex projects

As mentioned in the previous section, uncertainty does play an essential role in the field of project management such as in the field of road infrastructure. Therefore, uncertainty is explained to get a better understanding of this. Due to the complexity of construction projects, a series of cost overruns can be encountered over the years. The reason for this is that complexity and uncertainty appear in road infrastructure projects (Afzal, 2019). It is said that road infrastructure projects face a lot of different problems, compared to other projects, such as uncertainties, predicaments, immense complexity and probable risks.

Maylor et al. (2013) defined uncertainty as typically the result of novelty of technology or process, a lack of experience, a lack of availability of information, or some combination of these. Uncertainties need to be managed within all projects. The way to manage uncertainty in a project is to achieve the project objectives with the help of the process of risk management. The Project Management Institute defines risk as an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives (PMI, 2017).

The concept behind risk management is that it looks for areas for improvement in addition to addressing unforeseen issues. Therefore, it can be claimed that ambiguity might also be advantageous. Therefore, opportunities have a positive effect on project performance, whereas risk has a negative effect on project outcomes. In summary, the goal of risk management is to maximise project success by reducing the likelihood of unfavourable risks and increasing the likelihood of known hazards. To identify and assess conflicting incentives and perceptions in the risk management process, it could be useful to involve different stakeholders into the process (Qazi, 2020; PMI BoK, 2017).

Brink (2016) investigated the way in which the management of uncertainty can enable the sustainability of complex projects. The mentioned research was conducted through focus group interviews with 11 companies, 20 interviews and a seminar with 60 participants. One of the findings of the research was that it needs to be considered that risk and uncertainty are not the same. The definition of uncertainty was: “do not know that you do not know” (Brink, 2016, p.316). Risk can be described as follows: In the best scenario, outcomes can be calculated using the best and worst scenarios, and something is known about the occurrence. In a project, managing uncertainty through various approaches is essential. Project management is one of the primary tasks. At the end of a project, important problems should be considered. Afterwards, it must be considered from the start. This implies that resources must be used far sooner than previously thought. The other path is that every organization needs the capacity to explore and exploit important issues (Brink, 2016).

A grasp of the field of project management, complexity, and uncertainty has been developed thus far in the literature review. Since the study focuses on road infrastructure, general explanations have been provided for the various subjects. A more thorough literature review of the road infrastructure field was carried out in order to gain a better understanding of the specializations of

road infrastructure projects and to comprehend why complexity and uncertainty are playing such an important role in these areas. This will be explained in the upcoming sub-chapter.

2.2 Road infrastructure projects

In the context of road infrastructure projects, the performance and the success of a project are often discussed. Hence, the terms performance and success will be discussed in more detail in the following section, to provide a clear understanding of the challenges of a road infrastructure project and what is meant by the term successful.

The road infrastructure literature review's content gives a clear definition of road infrastructure, explains why these projects are so important, and explains how they differ from other civil engineering projects because the research's focus is on road infrastructure projects, which are known to be in the public eye. The performance and success of a project are frequently mentioned in relation to road infrastructure projects.

Therefore, to give a comprehensive knowledge of the difficulties of a road infrastructure project and what is meant by the phrase successful, the terms performance and success will be covered in greater detail in the part that follows.

2.2.1 Definition of road infrastructure and road infrastructure project management

2.2.1.1 Definition of road infrastructure

Surface roads, railroads, and terminals such as trucking terminals, train stations, and bus stops are examples of fixed assets that make up road infrastructure (Chandra Das, 2016). Roads and automobiles are not the only components of a road infrastructure network.

The transportation infrastructure also includes rail, transit, canals, ports, bridges and airport (Tonn et al., 2019). The chart below provides a more precise definition, as it is also found in other nations (e.g. Victorian Road Management, 2004).

Table 1: Road infrastructure accessories (Zander, 2015)

Road Traffic Facilities	Surface of the Road	Carriageway, Others (footpaths, cycle paths, parking spaces)
	Others	Drainage, earth body, substructure, planting, culverts, equipment, accessories
	Structures	bridges, traffic sign bridges, tunnel/trough structures, supporting structures, noise protection structures
Others	Service Area of the planning department	
	Building Constructions of the planning department	

The aforementioned figure makes it clear that the road infrastructure is divided into numerous portions. The vast field of road infrastructure project management encompasses more than simply highways; it also includes bridges, tunnels, and airports.

2.2.1.2 Definition of project management in road infrastructure projects

Spang (2016) outlines the following project management steps needed to complete a project in the road infrastructure sector. Road infrastructure project management is the planning, organization, implementation, control and management of a self-contained unique process.

This process is geared to a clearly substantive goal; it is described by a clear task and limited by a defined cost framework as well as essential deadlines.

Figure 3 shows the main phases of road infrastructure project management. Phase I of the process begins with the generation of the project idea, followed by the first analysis of the project and a feasibility assessment. Phase II, which consists of the planning and design tasks, is the fundamental component of the entire process. Depending on the project, this stage may extend for a number of years. According to the planning engineer, who was interviewed for this study, the planning phase of their current project is expected to take about ten years. Phase III, which consists of the orders and tenders, begins after Phase II is complete. Phase IV, the building phase, then begins. After this stage is complete, the project can be utilised, and it is handed over (Phase V).



Figure 3: Main phases of an infrastructure project (own presentation based on Spang, 2016)

Highways, roads, and paths are the primary areas of road infrastructure projects that are the subject of this study. Everything related to that topic, such as bridges, tunnels, public-private partnership projects (ppp-projects), etc., will be covered in the current study.

2.2.2 Megaprojects

When road infrastructure projects are discussed, they are often associated with mega-projects. Hence, in the next sub-chapter the term megaprojects will be explained in more detail. In the literature, there is no accepted definition for the term megaproject. Gellert and Lynch (2003, p.16) stated that: “Mega-projects can be divided analytically into four types: 1. Infrastructure (e.g., ports, railroads, urban water and sewer systems); 2. Extraction (e.g. minerals, oil, and gas); 3. Production (e.g. industrial tree plantations, export processing zones, and manufacturing parks); and 4. Consumption (e.g. massive tourist installations, malls, theme parks, and real estate developments)”. Megaprojects are strategic-aligned projects which deliver key strategic assets in large projects (Eweje, 2012). A more detailed definition is given by Bruzelius et al. (2002), who define a mega project with the help of five parameters. These parameters must be fulfilled independently:

- Investment volume > 1 billion US dollars,
- Life time > 50 years,
- High degree of uncertainty regarding demand and cost forecasts,
- Characteristics of a club property where exclusion of use is possible – e.g. by charging tolls and where there is at least partial rivalry in consumption,
- Indirect benefits that cannot be internalized by the operator.

Road infrastructure projects are one type of mega project. These projects are of utmost importance for any state or national government. Road infrastructure projects help in improving the quality of

our lives. (Aziz, Riaz and Arslan, 2017). And, as is mentioned above, the focus in this study is on road infrastructure projects.

The interchange of inaccurate, faulty, and fabricated information is one of the primary problems with megaprojects. As a result, the final portion of this literature review chapter will undertake a thorough literature study.

The other challenge that is faced is the conflicts between the decision-making parties, the policy, the planning and the public (Flyvberg, 2007). Project managers working in megaprojects are used to adopting the traditional methods of project delivery. In this way of working, everything is focused on time and costs and what gets lost is paying attention to how to get the best overall results (Asrilhant et al., 2007).

Because of the diversity of the objectives of megaprojects, a number of diverse stakeholders are involved. The concept here is that all the different stakeholders use different systems and represent other interests. This obviously leads to high socioeconomic, political interest and to high industrial and public attention (Turner et al., 2009). With these key parameters, the significance of the complexity in a road infrastructure project (mega projects) is highlighted again.

If one takes into account that the planning and construction of megaprojects will play an important role in the future, it must be realized that design and delivery are becoming increasingly important regarding the effective and efficient performance of a life cycle.

2.2.3 Stakeholder

Freeman (1994) investigated the meaning of the term stakeholder. Freeman and Maitchnik (2013) explained that a stakeholder is a person or group that has a legitimate interest in the course or outcome of a process or project.

Based on Freeman (1994), two questions need to be thought of in general:

1. What is the purpose of a particular company/project?
2. What responsibilities do managers have towards stakeholders?

What Freeman is focusing on is that the goal of a project should not only lie in the financial aspect; he mentioned that it is important that different groups of interests are involved.

Freeman's general idea of the stakeholder is as follows:

The project is in the middle and the stakeholders are put around the project in a simple radial.

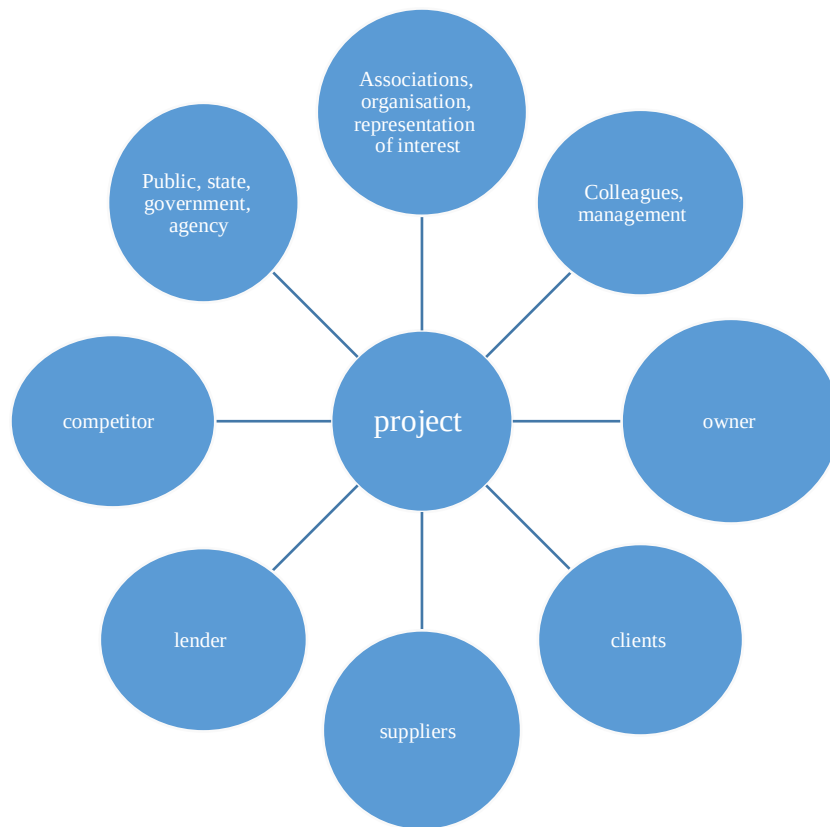


Figure 4:Freeman's understanding of stakeholder management (Freeman, 1994)

This paradigm states that the stakeholders are unrelated to one another. This alludes to the notion that each group operates independently. Since each stakeholder operates independently, as Freeman said, the study's hypothesis was that there should be more information sharing across the many stakeholders.

2.2.4Road infrastructure projects

Since time immemorial people have used roads and paths to overcome spaces. With the invention of motorized vehicles and the development of the first modern traffic networks, the foundation of our current road network was laid. Due to the technological and cultural development, the demands

on the infrastructure grew. Above all, the growing volume of traffic and transport of goods and the greater distances between home and work led to increasing traffic volumes. This was associated with progressive demand on the road infrastructure. Regular investments in the road network are now necessary to meet the increased demands (Tonn et al., 2019).

According to a 2019 study, the majority of people are now living in cities for the first time, and this trend is only getting stronger. The majority of transport services are located in cities and the areas that connect them. Accordingly, maintaining suitable living standards requires a comprehensive infrastructure (Wojewnik-Filipkowska et al., 2019).

Public transportation's quality is essential to society and daily living. Additionally, a green, low-carbon, energy-efficient, and sustainable environment must be the main focus of transportation (Narayanaswami, 2017).

2.2.5 Characteristics and challenges

What are the unique characteristics and difficulties of road infrastructure projects, and why are they so different from other projects? There is significant disruption to the environment and the living conditions of people, animals, and society when a road infrastructure project is being built. When planning a road infrastructure project, it is obvious that there will be significant disruptions over an extended period of time due to construction sites and logistics. Along with their high costs, large projects frequently rely on taxpayer assistance to support their operations. The difficulty of doing a thorough timetable planning for infrastructure projects is another pertinent issue, as elements like rock, soil, and the weather are all only somewhat predictable. As a result, adjustments to the planning and timetable are inevitable (Samset, 2014).

The field of road infrastructure projects is huge and can be split into a lot of different fields. One is to define road infrastructure projects as large Transport Infrastructure Projects (TIPs), which are associated with mega projects – see section 2.3.2 – in the transportation sector. The challenges that occur in these TIPs are mainly that they are delivered late, they are over budget and their benefit is less than expected. To overcome these challenges, the early engagement of external and internal stakeholders is necessary and also the financial support of the government (Locatelli et al., 2017).

Within road infrastructure projects, the expectation is high that they will deliver value to their stakeholders and users long after their completion (Martinsuo and Vuorinen, 2018).

The challenge of large infrastructure projects is that these projects are difficult to undertake and an abundant time for conception and development is required. What needs to be considered, is that a diversity of parameters needs to be managed. These parameters are time, planning, human resources, costs, risk prevention, change requirements and quality control. Metro development projects demonstrate how important transportation projects are, because they are spread out globally (Mohan, 2011). They are found in developed countries and in developing countries. Even for urban supply chain management, public transportation is an important component. Narayanaswami (2017) stated that a balance between planning and managing is necessary if the focus in a project is on project management, technology and quality.

It can be said that road infrastructure projects are different to non-infrastructure projects because other key stakeholders, for example the public, are included as well and these projects do have a value to society. This includes the government, the general-public, pressure groups, media and the firm involved in delivering the infrastructure (Bryde, 2020).

Common problems that arise from stakeholders in large infrastructure projects are repair and restoring work, cost overruns, poor communication and failure of the supply chain (Barlow, 2000; Yang et al., 2011). Road infrastructure projects are in the public eye: communication, transparency and participation are becoming increasingly important (Spang, 2016). These are just some of the topics which appear in road infrastructure projects, but they do highlight how demanding and complex these projects are.

The concept of trust is another extremely difficult subject. Numerous facets of trust are described in the literature (Schoorman et al., 2007). Scientists claim that trust is a one-dimensional concept and that it is almost inseparable in economic relationships (Zhang et al., 2011).

2.2.6 Complexity in road infrastructure projects

As complexity like structural complexity, socio-political complexity and emergent complexity are discussed in section 2.2.4, Figure 2-7 visualizes the term complexity in terms of the different stakeholders. The figure below gives a holistic understanding of what the environment of a road infrastructure project looks like. In the middle of the figure, the project itself is visualized. Around the project, the different groups that are affecting the project are visualized.

Figure 5 illustrates the concept of complexity in terms of the various stakeholders, where complexity such as structural complexity, socio-political complexity, and emergent complexity are covered in section 2.2.4. A comprehensive picture of the surroundings of a road infrastructure project can be found in the graphic below. The project itself is depicted in the centre of the figure. The several groups that have an impact on the project are depicted around it.

First and foremost, a thorough examination of the flora and fauna is required. This is the first way that unanticipated problems could impact the project. Every choice must be considered with the authorizing agency, starting with the planning stage. There is continuous communication with the building owner, the media, the public, the authorities, and the politicians throughout the project's duration. The red arrows indicate that every stakeholder has an impact on the project. Additionally, it is increasingly apparent that each stakeholder supports a variety of interests (Spang, 2016).

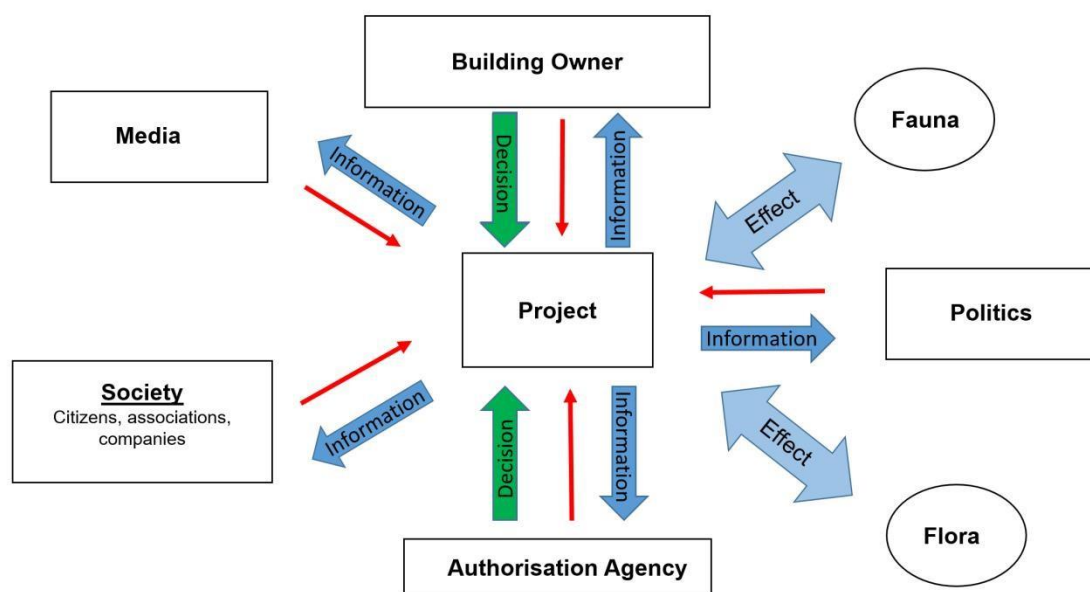


Figure 5 The environment of a road infrastructure project and who is affecting the project (Spang, 2016)

2.2.7 Performance and success of road infrastructure projects

Prior to undertaking an investigation into the meaning of performance and success, the general difference between the two needs to be understood. In principle, these two are known as CSFs (critical success factors) and KPIs (key performance indicators).

The Critical Success Factors are the factors that need to be delivered to achieve success in a project. These are the factors that cause the success. Differently, however, are the KPIs: these are the indicators that measure if a project is successful or not. The KPIs are the indicators that affect the actions in a project (Marr, 2011).

Both are combined, because without having a positive action in a project, the project cannot be delivered successfully, and without using the CSF, a project cannot deliver successfully either (Ionescu, 2015).

2.2.7.1 Performance

The golden triangle has already been mentioned several times in the current study. According to Jha and Iyer (2007), the performance of a project is normally measured with the three criteria of cost, time and quality. Measuring cost and time is different than measuring the quality of a project. The performance of quality is usually measured by technical standards or by agreements that were made in the contracts (Tabish and Jha, 2012). In contrast, the time and the budget are measured against the deviation from the time schedule or the budget planning that was made at the beginning of the project. In this context, the topic in terms of the complexity, regarding the different stakeholders in a road infrastructure project, arises again. As different stakeholders often have different interests in a road infrastructure project, this leads to the fact that the different stakeholders sometimes also have different performance criteria as well (Winch, 2010). This circumstance has the consequence that the limitation of project performance to the parameters of cost, budget and quality is inappropriate. Therefore, a supplementary parameter for the measurement of project performance should be included. According to Lehtiranta et al. (2012), this additional parameter should be the satisfaction of the client.

2.2.7.2 Success of road infrastructure projects

Prior to discussing the performance of road infrastructure projects, it is important to make a distinction between project success and project management success. When project management and project success are discussed simultaneously, there is no consensus, as noted by Pinot and Slevin (1988). According to the authors, "because we are unable to fully define a concept that can mean so much to so many different people, articles, cases, and other studies of 'successful' project management will remain of lesser impact" (Pinot and Slevon, 1988, p.1). There was no

counterargument uncovered in the current literature review. The definition of project success is not the same as this. Three factors: cost, time, and quality explain the project success criterion.

With all the information gathered so far, it is worth thinking about the performance of road infrastructure projects. Discussing performance is not simple. The understanding behind the meaning of performance is success and efficiency. But to describe the meaning of success again, Cooke-Davies (2002) mentioned that this needs to be separated into three different explanations. First, the factors that help in achieving successful project management need to be elaborated on. Second, the factors for a successful project need to be analyzed. Third, the factors for a constantly successful project need to be identified. In the context of this, the understanding of project success is that a project achieves its general goals. If a project is finished in time, in cost and to the required quality or performance, this is said to be project management success. De Wit (1988) also differentiates between success criteria and success factors. The success criteria are the ones which are used when the success or failure of a project is judged. And the success factors are the ones which are used in judging the success of a project. In this context, the needs of the different project stakeholders need to be considered, who are the ones who established the project, and what the benefits of the project are need to be analyzed and what it is expected to achieve (Cooke-Davies, 2002). Based on this, it was found that the benefits of a project are not delivered through a single manager or a team; they depend on the whole operation's management. This leads to the conclusion that it is more difficult to deliver a successful project, because it involves goals and the different methods.

Eray (2017) mentioned that a variety of factors are involved to deliver a project successfully. On the one hand, highly effective coordination and communication among project stakeholders is needed. And, on the other hand, delivering a project successfully also relies on real-time tracking, measurement of the project, progress and performance, risk detection and minimizing but rapidly adapting to imperative change. The authors of a Chinese paper (Turner and Zolin, 2007) identified four dimensions of project success. The first dimension is if an output is produced that makes it valuable in a special time and with appropriate costs. Secondly, if a desired outcome is achieved on time and with appropriate costs. Thirdly, if a positive net present value is delivered, and lastly if a business or public need is delivered at time and cost. These four dimensions are all related to time and cost. As a basis for this study, a study by Turner and Zolin from 2007 was used. In this paper, they identified the following three dimensions of a successful project, efficiency, customer

and the business. Whether or not a project is efficient can only be concluded at the end of the project. In order to be efficient, the project needs to be completed in time, in cost, with high functionality and performance. After the project is completed, the customer evaluates if it is successful with parameters such as requirements, specification, benefit, use, availability, reliability, maintainability and satisfaction. Turner and Zolin (2007) stated that the second level of success is achieved in the following years, after a project is completed. Hence, the parameter business is mentioned, which is measured in sales, profits, market share, return on investment, cash, cycle time, organization and approval. What was also found in the study by Turner (2018) is that sometimes success cannot be measured from a financial perspective.

In the current study, the goal is to focus on the delivery of project success and the delivery of successful project management.

Using success as an indicator for a road infrastructure project is very complex. Success can be interpreted differently by different individuals and different stakeholders. Depending on the individuals' preferences, the understanding of success is different. An example of this is that the understanding of success for a project manager is that the project is on time and on budget. In contrast, the investor, for instance, is more concerned about the long-term economic viability (Samset, 2014). This alone demonstrates the difficulty when several stakeholders are involved in a project.

It is also stated that road infrastructure projects impact people's quality of life. The infrastructure of a country is a value, with which the economic growth of a nation and its international competitiveness can be measured (Maghsoudi et al., 2016). It is important to highlight that a project is not only successful because of the goals that have to be achieved during it. More important is to achieve the benefits and values the TIPs should deliver (Ahola et al., 2008; Sehnar, 2001). A study in Australia found why in major road infrastructure projects innovation is so rarely used for the basis of the objectives in these projects. It is known that it is a challenge and very complex to implement and manage innovation itself. But, because of the risk-averse culture, benefits and great opportunities are being lost. The reason for that is that in road infrastructure projects innovation is not used like it is used in other projects. However, there needs to be consideration of how innovation can appear in road infrastructure projects and how it can be captured and produced (Maghsoudi et al., 2016). This study reflects the challenges in terms of new

technologies, which is the reason why research in the field of industry 4.0, in this study in BT, is conducted.

2.2.8 Examples of existing projects (successful and unsuccessful projects)

Road infrastructure projects are well known and affect the whole society. As has been examined so far during the literature review, road infrastructure projects have been discussed in the context of successful and unsuccessful projects. In the following section, examples of successful and unsuccessful projects will be given. In the present study, the understanding of successful projects is based on the traditional iron triangle shown in Figure 6. The iron triangle identifies three components that are related to a successful project. These components are cost, time and quality (Barnes, 1988).

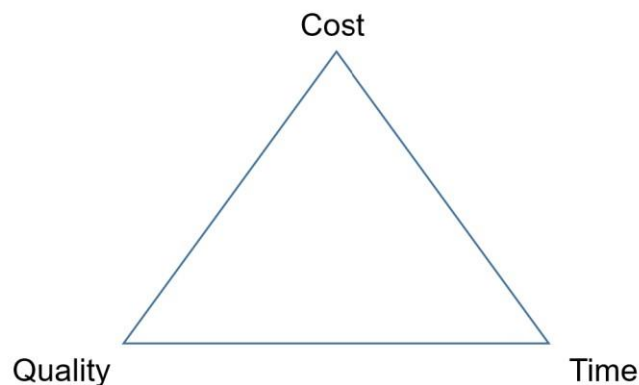


Figure 6 The iron triangle (Atkinson, 1999, p. 338)

A lot of road infrastructure initiatives are successful. Therefore, it is necessary to determine what can be learnt from them. One well-known and successful road infrastructure project is Switzerland's Gotthard Base Tunnel. This job was finished both on schedule and within budget. The Gotthard Base Tunnel is the world's longest railway tunnel. It is an excellent means of transportation between the south and north of Europe and takes 40 minutes to get through the Alps. One of the reasons that this project was successful was that all stakeholders were included in the organization of the project. The advantage of this was that it was possible to simplify contacts and

links, because of control, a better management, and transparency was feasible and, with the help of a lean organization, the project had better governance and efficiency (Fabbri, 2019).

The Gotthard Tunnel is 57 km long, the largest construction project in project management history in Switzerland. In total it took 17 years to build and was finished on the 1st of June 2017. This project is a showcase for excellent project management and highlights the importance of road infrastructure projects. Such a tunnel brings people and economies together ([Bluepm](#); Accessed, August 10th, 2020). What makes this tunnel so special and popular is that this mammoth project was built in time, in cost and with high quality (Spiegel, Accessed, August 10th, 2020).

Another well-known road infrastructure project is the Morandi Bridge in Genoa. Although the reason for rebuilding this bridge is a story with a really sad background, it is a good example of how to deal with a road infrastructure project and what needs to be optimized. And the new bridge is a good example of a successful road infrastructure project. On 14th August 2018, the old bridge construction collapsed. To this day, the reason for the collapse has not really been clarified. Apparently, it was known that the bridge was ramshackle but the necessary treatments were not implemented.

The reconstruction of the new bridge started in 2019 and was finished one year later. Normally, it would take three years to build such a bridge, but all the stakeholders involved in this project had only one goal. The reason for reconstructing this bridge as soon as possible was because the bridge is an important arterial highway for the seaport of Genoa. It is also one of the most important conjunctions from the northern to the southern part of France, Tuscany, Piedmont and Lombardy (Zeit, Accessed April 20th, 2021).

The reasons for the success of both of these projects are well-managed quality management, huge transparency in every construction phase and strict public controls (Tagesschau, Accessed April 20th, 2021)

As well as the successful road infrastructure projects, there are also a number of unsuccessful projects. The inefficient projects are especially found in the large and complex projects in the field of road infrastructure. The inefficiency is due to the large numbers of stakeholders included in such a mega project. When large numbers of stakeholders are included, various interests appear. The larger the project, the more difficult the authorisation procedure (Bryde, 2020).

An up-to-date and well-known mega project is the new airport in Berlin (BER) in Germany. It took 30 years to get it finished and it cost three times more than expected. At the beginning of

2007, a Danish man, Bent Flyvbjerg, published a major essay with the title: “Policy and planning of large infrastructure projects: Problems, identification of a cause, solutions”. This essay was published in the same time as the master builder of Berlin and Brandenburg started to get bogged down. In the essay, Flyvbjerg stated that the explosion of costs, incorrect forecasts and botch-ups of all kinds are worldwide phenomena, which are found in a lot of road infrastructure projects. He also mentioned the insufficient transparency between the different stakeholders in such mega projects, for example between the project managers and the politicians. What he proposed in the essay was that all the different stakeholders need to be involved in the whole planning, of a project, from the first step on (Flyvbjerg, 2007).

2.2.9 Learnings from the literature review of road infrastructure project management

Within the literature review of successful road infrastructure projects, the Gotthard Tunnel and the Morandi Bridge were mentioned. Both projects were successful in terms of timing, budget and quality. The mentioned reasons for why they worked were because of the transparent processes, all the stakeholders had the same goal, the stakeholders trusted each other and they had a good working information exchange. On the one hand, the information exchange and proper communication were mentioned several times, so this supports the researcher’s investigation of a proper literature review in terms of the information exchange. This needs to be done to get an understanding what an information exchange system is and why it can support the current study. It was mentioned so far that different stakeholders are involved in these large projects and normally they do not work in a transparent way, because of the missing trust. As the BT can be used if groups do not trust each other a literature review will be conducted in this field as well.

During the literature review of road infrastructure projects, the characteristics and challenges of these projects were named. In correlation with these characteristics, the literature review of BT and information exchange will be described in more detail. The idea came up that a thorough information management is needed in projects which involve so many different stakeholders. How the information exchange is working in these projects needs to be investigated. Prior to conducting the literature review of information exchange, the literature review of BT will be presented. As it has been stated that the Block chain Technology is a decentralized system and many different stakeholders can be involved, it needs to be proven in the next sections if it does make sense to use this technology in this research.

2.3 Block chain Technology Overview

Block chain technology is recognized for its decentralized, secure, and transparent nature. According to Nakamoto (2008), block chain allows multiple participants to have access to a shared ledger that is immutable and tamper-proof. This feature is particularly beneficial for industries requiring high levels of trust and accountability, such as transportation and infrastructure management.

Block chain Technology was initially introduced in 2008 by Satoshi Nakamoto and since then the technology has become more and more popular, with a peak in the year 2017. The technology has become the focus in the last years in a lot of business areas. The reason why it has become the focus is because of the role in the transformation of operational processes (Hamed, 2022). When Block chain Technology is discussed, it is important to know that this technology initially was created to support the currency bitcoin (Nakamoto, 2008).

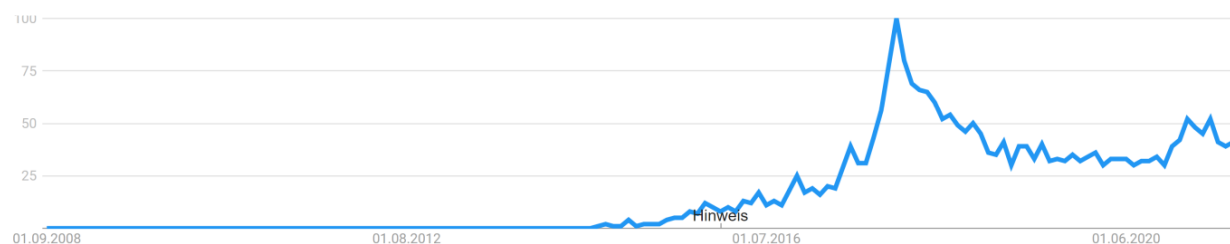


Figure 7 Number of searches for 'Block chain Technology' worldwide, according to Google Trends, 2020

The system of Block chain Technology is working as follows. The structure of every block in a Block chain Technology is made of transactions. All transactions that are made are recorded through distributed databases and contributing nodes. The nodes in a Block chain Technology are known as miners. As these systems bring security to transactions it is used when different parties do not trust each other (Loukil et al., 2021).

Block chain Technology is probably a technology that can lower the costs of institutional entrepreneurship along industrial dynamics, technological change and innovation. It is uncontroversial in the experimental phase of development regarding technological, economic and political uncertainties, but it is certainly the core component of the future generation of the internet. Block chain Technology is an internet-based decentralised economy. It provides a digital platform for digital assets, digital currencies, digital identity and smart contracts. Different to other platforms or systems, which are governed centrally, Block chain Technology is managed, distributed or decentralised through a tremendous number of token holders, block validators or

developers. Since 2008, there has been a lot of development around that technology (Allen et al., 2020).

In recent years, Block chain Technology has become more and more important and well known. The author who introduced the crypto currency bitcoin in a whitepaper, called “Bitcoin: a Peer-to-Peer Electronic Cash System”, in 2008 is called Satoshi Nakamoto. So far, it is not known if Satoshi Nakamoto is a person or a group of different people. Nakamoto developed a special payment system, with which the token can be transferred directly between two parties, without using an intermediary. The famous application of Block chain Technology is the digital cryptocurrency bitcoin. Nakamoto’s aim was to develop a technology to close the gap of trust (Laurence, 2017). But what is behind that technology, becoming more and more popular, is called Block chain Technology. It is called Block chain Technology because this technology is a distributed transaction ledger with a decentralised database in which different computers which are also known as nodes cooperate as a system (Lemieux, 2016). So far, 80% of the total block chain asset market capitalisation is comprised of bitcoin (Yeoh, 2017). According to the World Economic Forum, by 2025, 10% of the world’s GDP may be on Block chain Technology (Zalan, 2018).

The idea of the current research is to see if there is a way to combine Block chain Technology with the information exchange and the road infrastructure projects because of the significance of this technology for the future and the issues that are faced in the field of road infrastructure projects. Block chain Technology can be used to address issues associated with information integrity in the present and near term, assuming proper security architecture and infrastructure management controls (Lemieux, 2016). This analysis from the year 2017 is also a reason why the idea is to develop a framework for the utilisation in managing road infrastructure projects with the help of the principles of Block chain Technology.

Studies have shown that Block chain Technology is at the heart of the latest attempt to improve transparency, efficiency and security across a wide range of value transactions. It has been found that Block chain Technology is having its first disruptive effects in different industries (Frizzo-Barker et al., 2019).

Block chain Technology is worthwhile if you want to share information with parties you do not fully trust, if your data needs to be verified or if there is a risk of your data being manipulated

internally or externally. None of these issues are easy to solve and it can get very complicated to find the right solutions (Laurence, 2017).

What was happening within institutions and companies, and still keeps going on, is that people do not trust each other or have lost the trust to their institutions (Lemieux, 2016). This was also one of the reasons why the Block chain Technology was developed, to create digital trust within people working together and in institutions. The advantage of this technology is that, with its help, an agreement is achieved which can be used between parties who do not trust each other. “Together, we are entering the trust age” (Mazzella et al., 2016, p. 31).

The Block chain Technology system allocates an interface, a technical infrastructure, a process guidance and a service such as insurance for establishing trust between the different parties (Katz, 2015). It also provides transparency of the processes without giving the information about who or what is behind the receiver. This works with the help of a code. For somebody who is using Airbnb, one of the most important issues is that the participants trust each other and behave in a thoughtful and respectful manner. On the other hand, it is important to note that, in terms of the booking and payment, these processes need to run smoothly. For the user themselves, who is behind the transaction this is not the most important thing; the most important thing is that the transaction and process itself is transparent (Hawlitschek et al., 2016a). And this procedure can be supported by Block chain Technology, as it is possible to use different kinds of Block chain Technology.

The block chain database works because of a clever mathematical algorithm. Another advantage of this technology is that it can be used through large networks on many different computers located in places all over the world by many people (Shrier, 2020).

The terms bitcoin and block chain are often used interchangeably, but they do not mean the same thing. Bitcoin has a block chain. The Bitcoin Block chain is the protocol that enables the secure transfer of bitcoins. The term bitcoin is the name of the cryptocurrency on which the bitcoin network is based. The block chain itself is software; bitcoin is a specific cryptocurrency (Laurence, 2017).

This is the same as a road and a car, which are not the same but are mentioned in a similar context. For example a car needs a road to move effectively from point A to point B but a road can also be used for buses or bicycles.

2.3.1. The bitcoin block chain – an illustrative example

Terms which are used when discussing the Block chain Technology are distributed ledger, blocks and mining. To provide a better understanding of the Block chain Technology system, it is described in the following with the help of a Bitcoin Block chain.

2.3.1.1 Distributed Ledger

The common centralised systems we are used to working with are vulnerable to hacking or other breaches. It is insufficient to have access to only one system and a lot of accounts since processes or records can be changed. There is no copy of it which can prove that a process was changed. In the present time, this is becoming a major issue, when something is managed centrally by a government and when in the worst case you do not trust the government. The advantage of a distributed ledger is that there is a record or a ledger available that has many identical copies. The system of a distributed ledger ensures that the copies can talk to each other, automatically update themselves and that, if one record is hacked or changed deliberately, the other copies will fix the problem and show what really was changed. This gives the advantage of providing transparency of a whole system, from the beginning on, and can make processes traceable and immutable (Shrier, 2020; Laurence, 2017; Zamani, 2018). A distributed system is a system which is spread across different servers, saving the copies and spreading them out again across different servers (Gordon, 2018).

2.3.1.2. Blocks

In the context of Block chain Technology, immutability is mentioned. Block chain does help in terms of trust and immutability. But how can this be guaranteed? The understanding of a process that can be trusted is a system in which every transaction can be seen and a ledger can be altered. To create such a system, a mathematical solution was developed. With the help of Merkle trees it is possible to create an immutable history of transactions. An example of a Merkle tree can be seen in the figure below. The system of a Merkle tree works like this: one block in such a tree is set at a number of calculations. The output of the first block is used for creating the calculation for the second block. For the calculation of the next block, the output of the second block is used, and so on. As a result, it can be said that it is not possible to change something in the second block without affecting the output of the first and second blocks. The figure demonstrates how

this system works. What makes a block chain so special, is that every block is encoded with the help of hash-functions. This gives another level of security that a process cannot be hacked or breached (Shrier, 2020); (Laurence, 2017); (Zamani, 2018).

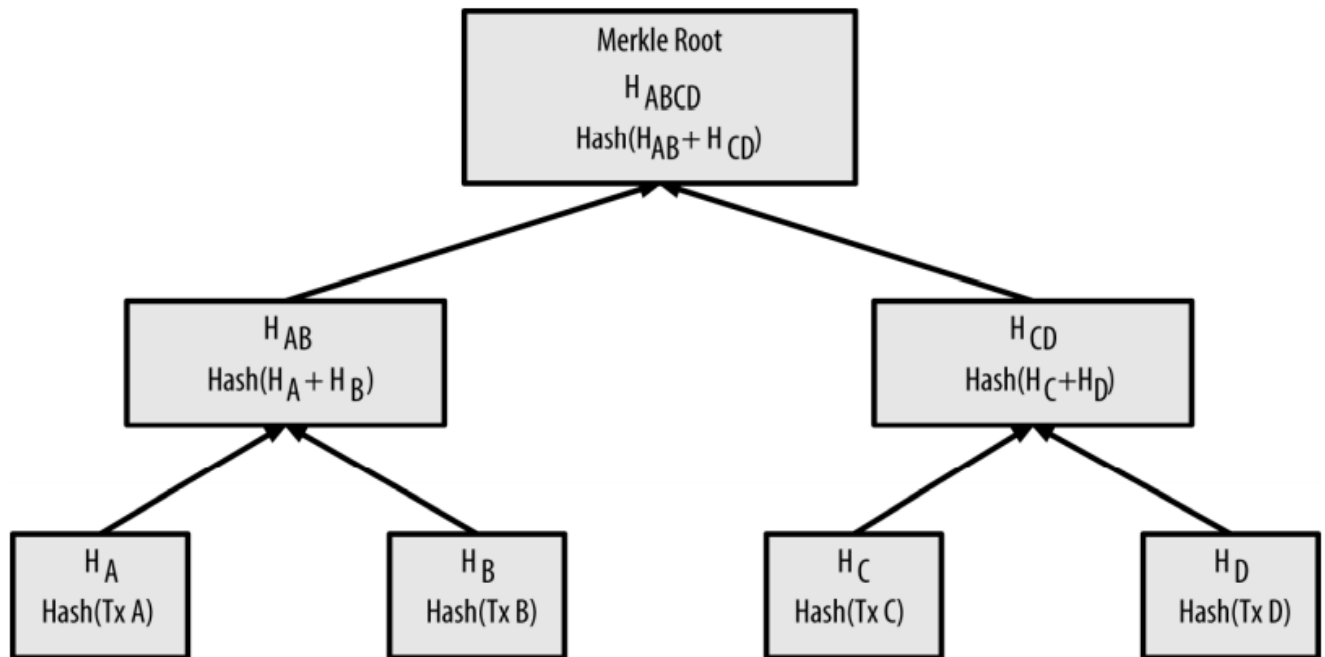


Figure 8 Merkle tree of a block chain (Shrier, 2020)

2.3.1.3. Mining.

Mining in a block chain can be compared with a mystery. There are different ways of earning a bitcoin. In the process of bitcoin mining, you earn bitcoins as you are getting part of the network. For this, there are special mining software packages around (Laurence, 2017); (Easley, O'Hara and Basu, 2019). A lot of different miners are behind creating a code for one block. Whoever creates the code first, gains an incentive. In the Bitcoin Block chain, the prize a miner gets is a bitcoin.

2.3.1.4. Chain

A hash key links the blocks, mathematically concatenating them. This is one of the most sophisticated block chain concepts and not very easy to understand. But it is precisely this seemingly magical mechanism that binds block chains tightly together and enables mathematically-based trust. The hash key in block chains is generated from the data of the previous block in each case. It is a fingerprint of this data that immutably fixes its rhine sequence and time (Laurence, 2017); 49

2.3.2 Principles of block chain technology

Firstly the term Block chain Technology has to be understood. A Block chain is a decentralized transaction and data management technology developed first for Block chain cryptocurrency (Yli-Huumo, 2016)

As in the study, the focus is on the principles of Block chain Technology; they will be summarised in this sub-section, based on the knowledge the research obtained through the reading. BT is a technology based on a decentralised procedure. This leads to the conclusion that the principles of the technology are that transparency can be generated during a process or a project. With the help of the technology, it is possible that the process itself can be transparent, but the group/stakeholder behind that process can be made non-transparent. Because of the transparent parameter, processes in a project are traceable and immutable.

This means that, if a term needs to be changed, it needs to be understood why it was necessary to change it. A good way of using the principles of BT is when discussing projects in which a lot of different stakeholders and groups are involved. The system of a BT is working as the following. A block chain is parted into a lot of different blocks, whenever a new set of transactions is generated a new block in the structure of a block chain is made. All these blocks are performed by nodes and these are known as miners. Based on this system, transactions can be used in a distributed way that is not related to a central party. The quality of the decentralisation of the BT brings the feature of trust, traceability, transparency and immutability (Hames, 2022). Distributed Ledger technologies as Block chain technologies promise to create an information system that is transparent and does make processes immutable.

2.3.2.1 Explanation of the principles of the block chain technology based on an example

To get a better understanding of the Block chain Technology and to be able to bring the Block chain Technology into the context to industry 4.0, as an introduction, the different industries will be explained and, based on this, the origin of Block chain Technology was generated. The path of the industries is visualised in Figure 9.

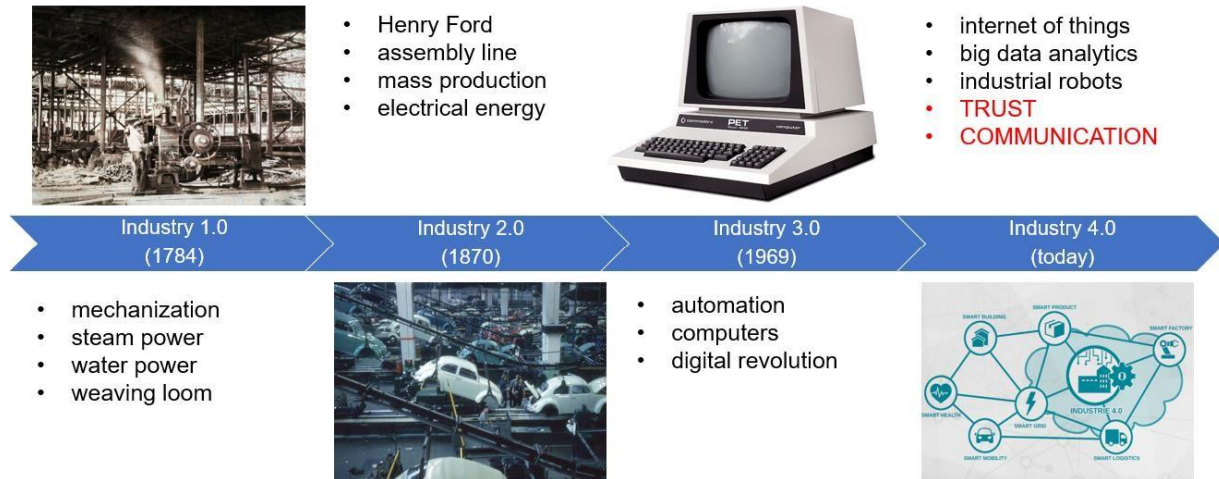


Figure 9 The path of industry 1.0 to industry 4.0 (own representation)

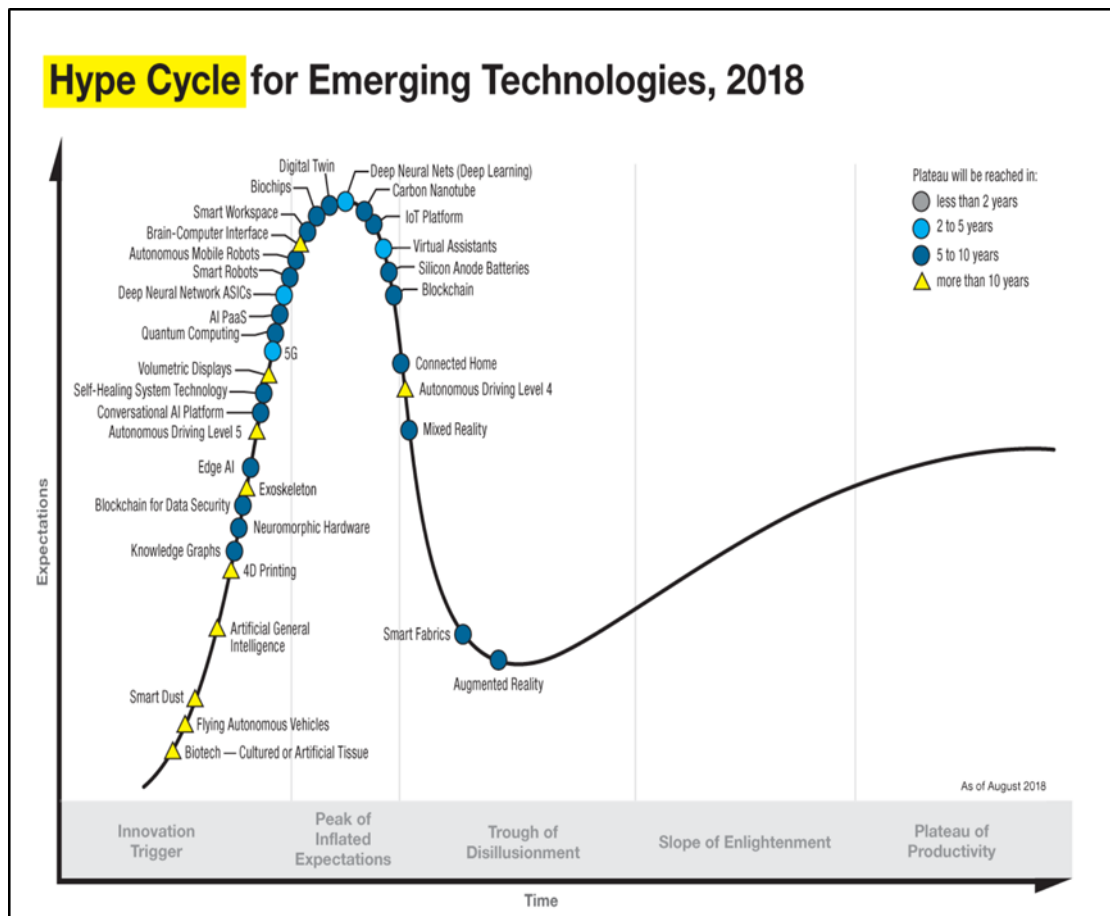
Whenever the topic of digitization arises for the first time, sometimes it is not clear what the meaning of this big term “digitization” exactly means. To define the scope of this, normally the term is related to industry 4.0. The term industry 4.0 is explicitly based on digital innovations (Kleemann, 2020). Bauernhansel (2014) noted that industry 4.0 can be traced back to the revolutionary phase of development. Each of these eras changed the industry in terms of an increase in productivity.

Industrialization started in the year 1784 with the creation of, for example, steam power and water power. With the help of these, production, with regard to mechanization was possible. In industry 2.0 (1870), electrical energy was used and Henry Ford implemented the assembly line; mass production was launched. The digital revolution started with industry 3.0 in 1969 with automation and optimization of production processes. The first computers and the use of electronic and information technology were a great development for this industry. After this, industry 4.0 was achieved. Topics in this industry are the internet of things, big data analysis and industrial robots. This industry is also known in terms of autonomisation and intelligent predictive optimization of entire production systems (Kleemann, 2020). One of the technologies in this digital age is the decentralized Block chain Technology.

Figure 2.13 shows in which state Block chain Technology stood in the year 2018 in the Hype Cycle for Emerging Technologies. The year 2018 was chosen as this was start of the present study.

The Hype Cycle is one of the most well-known tools for assessing the potentially transformative technologies across different industries. Traditionally, it has been assessed by measuring strategic planning, innovation and emerging technology that will have a huge impact across different businesses. As Panetta (2018) mentioned, Gartner assumes that every newly developed technology succeeds through a pattern of maturity and adoption. As can be seen in Figure 10, every technology follows a special way through different ups and downs. In principle, the hype cycle is grouped into five categories: the innovation trigger, the peak of inflated expectations, trough of disillusionment, slope of enlightenment and the plateau of productivity. Another description for this is: on the rise, at the peak, sliding into the trough, climbing the slope and entering the plateau.

Simon Sinek (2015) explained that this curve can be compared with the diffusion theory. The first 2.5% of our population are our innovators, they are in the category “innovation trigger”. In the category “peak of inflated expectation” are the next 13%, the early adopters. The next 34% are the early majority, 34% are the late majority. What the curve is saying, is that if a technology is to become successful it needs to turn over the tipping point of 15% to 18% market penetration. When this explanation is compared to the below figure, it can be seen that Block chain Technology is almost one step before the tipping point. That was also one of the reasons why this technology has been chosen in the research. To obtain a better understanding of the technology, its principles of are explained in the following.



Source: gartner.com/smartwithgartner

Figure 10 Hype cycle for emerging technologies, 2018

To explain the principles of Block chain Technology, the idea of Satoshi Nakamoto (2009) was used. The question Nakamoto is asking with the idea of Block chain Technology is: “How can digital transactions be carried out efficiently and securely in complex networks”?



Figure 11 Centralized system – bank (financial institution)

An explanation that supports the idea of the central system is the banking system (financial institutions); see Figure 11: Centralized system – bank (financial institution). Basically, the system works like this: the money is stored at the bank and if A wants to transfer money to B,

A gives the order to the bank. After the bank receives the order, it makes the cash transfer to B. Because this is a service provided by the bank, A is dependent on the bank and A needs to trust the bank, that the bank will make the transfer. Normally, a fee has to be paid for the transfer. In case the system of the bank is hacked, the money is not stored safely in a central system.

The system of a decentralized system, as for example a Block chain Technology, works differently; this will be explained with the help of Figure 12.

Basically, three requirements need to be fulfilled so that a Block chain can work:

An open ledger is available.

A decentralized system exists.

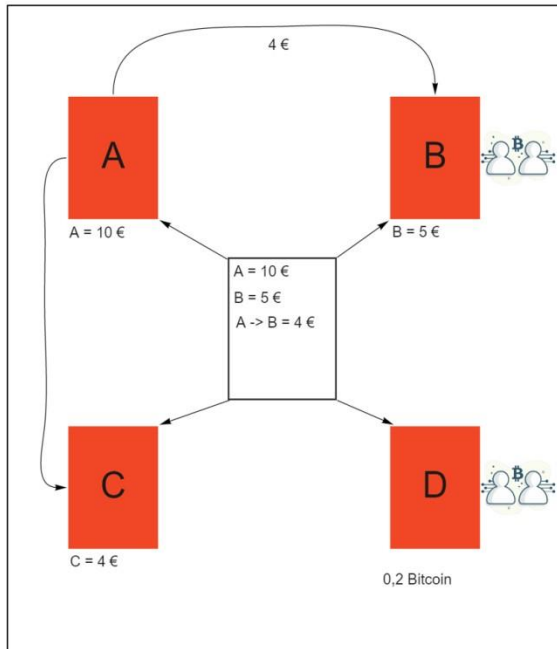
As an incentive, mining is used.

For example, in Figure 12 four participants are involved in that block chain. What the block chain is known for is that all the information and processes are transparent for everybody involved in the block chain. It needs to be highlighted that only the processes and the nodes are transparent; it is not known who is behind A, B, C or D; this information is anonymized. In the existing case, A, B and C all have a specific amount of money available. This information is stored in the ledger in the middle of the figure. This is the so-called open ledger. The difference to a centralized system is that this ledger is not stored centrally; whenever new information is added into the ledger, a lot of duplicates are made of this ledger and all the duplicates are encrypted with a special code that nobody knows. The duplicates are stored on several servers and are linked to each other; this means that it is not possible to hack one.

This is known as a decentralized system.

For example, all the participants know that A has \$10 and B has \$5. It is also visible to all that A is transferring \$4 to B. Just in case B says that A has not transferred the money, the system is visible so all the participants can see that B is wrong.

As in the system of the Bitcoin Block chain, no central system or tool is available that is managing the system, so-called crypto miners are around, that are managing the system in a Bitcoin Block chain. These miners do record, verify and book all transactions into that open ledger. As an incentive, they receive bitcoins.

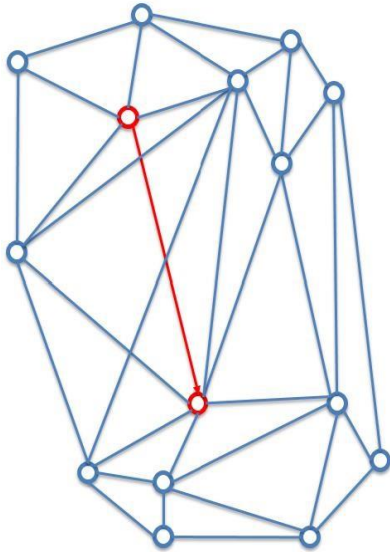


Requirements for a Blockchain:

1. Open ledger ✓
2. Decentralisation ✓
3. Mining ✓

Figure 12 Decentralised system – Blockchain Technology

Figure 12 shows the themes of a complex network. And when it is talked about the Block chain Technology, it is talked about a complex network. All potential participants do want, that their data and values are stored safely. This means, that it needs to be ensured, that these data cannot be hacked. The participants also expect that the transfer of information for example, will happen without high costs and time expenditure. And as it is expected, they are not to be hacked, it is also expected that they are not manipulated by the participants. So it can be summarized, that the receiver and the sender do want the same circumstances from different perspectives. The receiver wants to be sure that the sender also owns the good to be transmitted and the receiver wants to be able to prove with certainty that he also transferred it.



All participants in a complex network want:

- To store values safely
- To transfer values without high costs and time expenditure
- No manipulation of the transaction

Receiver wants:

- To be sure that the sender also owns the good to be transmitted

Sender wants:

- To be able to prove with certainty that he also transferred it

Figure 13 Complex networks

The principles that a BT provides, because of the distributed ledger or the decentralized system are the following:

Transparency is given,

Related to the transparency, process for example can be made traceable, so it can be talked about traceability,

This traceability leads to an immutability of information, documents and processes,

These three themes lead to the fact, that with the help of the principles of BT systems offer trust.

2.4.3 Advantages of block chain technology

One of the big advantages of Block chain Technology is the transparency which is given through it. This transparency leads to immutability, but what does this mean? What is written in the chapter in the introduction to Block chain Technology, is that one of the reasons why it was developed is because of the lost trust, people and institutions are facing. Another big advantage of Block chain Technology is that it can help in understanding where something comes from. This means that the provenance is known Talking about trust again: trust can be built in a way in which processes are visible and that a process or transaction cannot be changed. This is the main reason why BT was developed in the field of finance. People who are working in this sector do know that, with using this technology, although different flows of funds are needed, it can be trusted. The issue with trust is known in lots of different areas in our society. This is also an upcoming problem in the field of

information sharing, for example through the internet. Thus, Block chain Technology can help in decreasing the distrust of people (Gordon, 2018). A further intriguing potential use case for a block chain is as a completely reliable data storage system. An unambiguous chronology that documents who did what and when can be produced using a block chain. Numerous sectors and authorities have devoted numerous hours to assessing this issue. Blockchain-based records remove some of the difficulties in interpreting past events (Laurence, 2017).

2.4.4 Disadvantages and challenges of block chain technology

As already mentioned, Block chain Technology is a very complex technology which also has some disadvantages and is not useful in every part of the industry.

If the idea emerges to use a block chain, the tremendous electric power consumption needs to be considered. In order to make this visible, it is worth comparing a bitcoin transaction with a VISA transaction. A bitcoin transaction takes 819 kWh whilst a VISA transaction takes 0.0082 kWh. This means that, in terms of the electric power, a bitcoin transaction takes 100.000 times more electronic power than a VISA transaction. A bitcoin transfer costs €200.00 for average German electricity consumption. It also can be said that for one bitcoin transaction you can use a refrigerator in Germany for eight months (Bund-rvso, accessed May 18th, 2020).

The other issue with this technology is that there have been few experiences with it and it is very complex to implement. There are a few pilot projects around, but companies are still afraid of implementing this new technology (van Hoek, 2019); (Leon, 2017).

Even though Block chain Technology offers many advantages, it needs to be mentioned that there are still some challenges to overcome. The first challenge is the selection of time-resilient cryptographic hash-functions. The cryptographic hash-functions are essential to implement a distributed ledger system, which has the correct and secure design and implementation. The last one is the adequate selection and implementation of efficient, robust and trustworthy leader election algorithms (Leon, 2017). Leon (2017) also supports the fact that we need more research in the field of Block chain Technology. Leon describes the first misconceptions which are possible in Block chain Technology so is it true that Block chain Technology is safe, secure and trustworthy? The finding of this paper shows, as well, that more research on Block chain Technology will be needed to ensure that this technology is secure and that the developed systems are trustworthy, before its use becomes widespread.

2.4.5 Applications of block chain technology

Due to the main properties of Block chain Technology as traceability, transparency, immutability, smart contracts and security the technology is used in manifold areas including government elections and logistics (Pu, 2020). The innovation of BT is occurring in a lot of different industrial sectors, starting with the finance sector, including agriculture, healthcare, creative industries and government services (Allen et al., 2020).

As already mentioned, 80% of the successful implementations of BT have been in the finance sector (Yeoh, 2017). During the past few years, Block chain Technology has also started to be implemented in different sectors. The first study of BT, next to the finance sector, was made in the food industry, which was released in the British Food Journal in 2018 (Sander, 2018). The purpose of this paper was to generate a holistic picture of various perspectives of the traceability and transparency of systems in the food supply chain. The issues in the food industry are that the customers are overwhelmed by the current certification systems, and that labels are hard to understand and distinguish in terms of their relevance and credibility. Because of that, the Block chain Technology could be a good solution to provide an overview (Wang et al., 2019).

The European Commission is also looking at Block chain Technology. It is looking seriously at the potential of Block chain Technology and the distributed ledger technology (Miseviciute, 2018). The issue at the moment is that too many people think that it is too early to implement this technology. Regarding this, it is important to have a lot of studies in a lot of different fields, to convince not just the EU to work with the Block chain Technology (Leon, 2017).

There are several fields in which Block chain Technology has been used so far. One big field is the energy and food sector. The reason why it is used here is because, with the help of Block chain Technology, the client is able to understand where something came from. In terms of the food sector, this can be useful in food safety and in improving the economies of the farmers. Looking to the energy sector, it can be seen that the production and the delivery of energy can be improved. The result of this is that the financial market in this sector is becoming more effective. In the health sector, the first experiments are starting regarding lower costs and improved care with the help of BT (Dave et al., 2019). Research is also being conducted regarding to what extent the technology is helping in clinical research and if there is a possibility to speed up the time to market for lifesaving drugs. In the real estate sector, the technology is already successfully in use. It is traceable in terms of who bought, sold, developed and maintained the building, for instance.

Other sectors where it is starting to be used are the field of education and in governance itself (Shrier, 2020). Another field in which it is receiving attention is the supply chain field. A study executed by Vivaldi (2020) wanted to find out where the principles of Block chain Technology are applicable and in which supply chain fields it can provide successful results. This study relates to the traceability of products and the transparency of operations within a process. It has been proved that an advantage of the technology is the given safety and speed of information. Challenges which are currently arising concern the multiple platforms used in projects. Thus, it is valid that a vast level of connectivity for the multiple platforms is required. In this day and age, the society needs to deal with an increasing number of innovations and improvements. The question which is arising together with this is if the technology can have a positive influence in current processes in existing and upcoming projects (Vivaldini, 2020). Adoption of new technologies – block chain technology

In the last few decades, the implementation and the understanding of new technologies have become increasingly important. The diffusion of new technologies restructured work spaces and is leading to new skills and capabilities (Bartel et al., 2003; Bresnahan et al., 2002). The challenge behind new technologies, especially behind the information technologies, is that, for firms and companies, new technologies still are kind of a black box (Antonietti, 2005).

Antonietti (2005, p.3) mentioned that “adoption refers to the stage in which a technology is selected for use by an individual or an organization, namely the firm”.

An analysis was conducted through the UCL Centre for Block chain Technology about the adoption of Block chain Technology in supply chains between 2010 and 2020. During this research, 271 block chain projects were analyzed based on parameters like inception date different types of block chain and sectors applied to different organizations that founded a block chain pilot project (Vadgama and Tasca, 2021). The characteristics of DLTs are that they are able to make processes transparent and immutable. These properties represent tremendous progress in the supply chain field. The field of supply chain management still requires a lot of manual procedures and a lot of paperwork. Normally, the undertaking of complex supply chain projects takes a lot of different interactions and communications. With the help of BT, the shipment of flowers between Africa and the Netherlands saved 20% of time and 15% of costs, compared to the years in which the technology was not used (Maersk, IBM, 2017).

2.3.6 Summary of the literature review on block chain technology

Gathering the most important parameters of Block chain Technology and summarizing them into the principles of Block chain Technology, it has been learned that this technology is based on a distributed ledger. As the distributed ledger can be used in a large network society, this leads to the fact that it can be used when a huge number of stakeholders are involved. The main reason for using a Block chain Technology is to use it when little trust is available between the different groups of a project. What the distributed network delivers is to make processes transparent and secure and this combination of processes is traceable and immutable. And it needs to be investigated in the data collection, if is the principles of the BT also support the collaboration of people, processes and technologies.

2.4 The interaction of information exchange and block chain technology

2.4.1 Introduction

To deliver a successful road infrastructure project, several parameters need to be analyzed and investigated. In the thesis research between information exchange and BT also will be undertaken. All the themes that are involved into information exchange will be explained in the following sub-chapters.

2.4.2 Communication management

To ensure that the information needs of a project and its stakeholders are met, proper communication management in a project is required. The communication management in a project consist of two parts. In the first part, a strategy is developed that will ensure that the stakeholders do have effective communication. In the second part, the operations that are necessary for the implementation of the communication strategy are carried out. The processes of the communication management in a project are:

Planning of the communication management means the process of developing an appropriate approach and plan for project communication activities based on the information needs of individual stakeholders or groups and the resources available to the organization and the requirements of the project. Managing the communication entails ensuring that project management information is collected, created, distributed, stored, retrieved, managed, monitored and submitted for final disposal in a timely and appropriate manner. Monitoring the

communication is the process to ensure that the information needs of the project and the stakeholders are met.

In the field of the fundamentals in communication management, various approaches are possible. The term communication can be traced back to the meaning of whether it is an intended or unintended exchange of information. In terms of the information exchange, it can be a matter of thoughts, instructions or feelings. The exchange of information takes place, for example, with the following mechanism:

In written form; either in tangible or electronic form

Communication describes the possible means by which information can be sent or received – either through communication processes such as meetings and presentations or through artefacts such as e-mails, social media, project reports or project documentation. Project managers spend the majority of their time communicating with team members and other project stakeholders both within, at all organizational levels, and outside the organization. Effective communication bridges the gap between individual stakeholders who may have different cultural or organizational backgrounds, expertise, perspectives and interests (Röttger, 2013; Deekeling, 2017).

The processes of communication have many dimensions. The most important ones for the field of Block chain Technology are listed in the following:

Internally: alignment with the stakeholders in the project and in the organization

Externally: alignment with external stakeholders such as customers, suppliers, other project organizations, the state, the public and environmentalists

Formal: reports, formal meetings, regular and spontaneous meetings, meeting agendas and minutes, stakeholder briefings and presentations

Informal: general communications via e-mail, social media, websites and informal, spontaneous conversations

Hierarchical orientation: general communications via e-mail, social media, websites and informal, spontaneous conversations

Written and oral: verbal (words and tone of voice) and non-verbal (body language and actions) communication, social media and websites, press releases (PMI, 2017).

As the communication and the information exchange have been mentioned most in the literature review so far, a deeper investigation of the information exchange will be conducted in the next part.

2.4.3 Information exchange

In recent years, there has been an increasing interest in the data-driven information environment (Milne, 2015). In association with this, topics such as personal data ecosystems and technologies that enable the collection and dissemination of information are gaining increasing importance in project environments. Information is basically used so that consumers and businesses are able to make better decisions in their marketplaces (Milne, 2015).

Although the information exchange is an important aspect regarding communication, coordination and problem solving that is widely used in distributed systems, unfortunately it is handled secondary and has not been the focus of the research in the past (Dodds, Watts and Sabel, 2003). Another upcoming problem is the unwillingness of sharing data. Studies that researched the unwillingness of sharing data have reported about problems with confidentiality (Zhang, 2008; Tan et al., 2016), competition (Ha and Tong, 2008; Huo et al., 2013) and lack of trust (Tran et al., 2016; Kembro et al., 2017). Nevertheless, a considerable amount of literature has been published on information exchange. This literature distinguishes information exchange as having an essential role in the performance in different areas, such as, for example, airline, infrastructure and transportation networks as well as file-sharing systems and communications networks (Faloutsos et al., 1999; Gerth et al., 1946 and Taylor, 1911). Taking this as a base, nowadays information assists in identifying problems at their sources by accessing real-time information and improving transparency go hand in hand (Nakasumi, 2017).

For the data transfer between construction organizations and their clients, there are different technologies around. The general name of these technologies is Information Exchange (IE) (Baldwin, Thorpe and Carter, 1999). Baldwin, Thorpe and Carter's (1999) study found the benefits in alliance projects. Using IE does help in the promised delivery of data; it supports in improving the quality of the data; the communication between the partners in an alliance is improved, which leads to the fact that the risk of project delay is reduced. These findings were facilitated by 67 surveys.

The Information Exchange Theory digs even more into the topic than just the data transfer.

The theory aims at the study and modelling of information exchange processes among interacting agents. The concepts of protocols, types of information systems, misinformation and information distortion, codification and information distance are introduced.

As was already discussed in the stakeholder section, there is a need to investigate information exchange.

As mentioned by Jia et al. (2011), because of the reduction of the pace and the quality of the information exchange in a project, the efficiency is also reduced. With this statement, a question arises concerning the meaning of information exchange and how this is related to road infrastructure projects. Based on this, how the principles of BT can help in the field of information exchange needs to be investigated.

The previous sections described that several parameters between the different stakeholders need to be managed through the project managers. In correlation with this knowledge, transfer and information exchange is a high priority.

A general meaning of the term information exchange is that people pass information from one to another. The understanding of this is that data are shared between a sender and a receiver (Milne, 2015). Jacob and Varghese (2018) categorize the importance of an information exchange in the design process. Through a structured approach, it is possible to forecast and manage an information exchange. In this research, it was also detected that special information exchange models can be used to improve the life cycle management. There are different methods of information exchange. It can be done electronically or through certain systems. Another method of information exchange is through telecommunication or protocols (YoungYbarra, 1999).

2.4.4 Information exchange theory

When the question arises what information sharing supposes to do, it seems like it is a simple question. The focus is to share information (Chang, 1982). And from a general understanding an information exchange also supports a better security of people, data and processes (Jackson, 2022). The Information Exchange Theory (IET) itself is the theory of modelling the information exchange process between interacting agents. As already mentioned, a lot of different stakeholders are involved in a road infrastructure project. Freeman (1995) mentioned that every stakeholder is working in its silo, which gives the impression that there is no proper communication between the silos. With the help of this research, it will be investigated if the information exchange based on the principles of the BT can provide support here.

One part of the present research is to obtain an understanding of where the society and the different companies are in the period of industry 4.0 in the field of implementing information exchange in the road infrastructure sector.

Talking in the construction industry about information management, the question arises whether information management is the same as document management or if document management is part of information management (Gyampoh-Vidogah, Moreton and Proverbs, 2003). Joia (1998) found that only a small part of the documentation is online and most of the information is on paper. Another issue with the communication is that the information an engineer is getting is often outdated, and engineers do spend more time in search of documents than using them. The challenge in looking through documents and finding the correct one is to find the most recent version. This ends up in a process where documents are created from scratch again and again.

Doney and Canon (1997) and Mayer et al., (1995) mentioned that trust normally has been embedded in social interactions. For instance, does the literature propose “*that trust development is conventionally associated with relational governance mechanism according to the information exchange theory*” (Xu et al., 2022, p. 1879).

A well-known process which is helping in terms of information exchange is BIM (Building Information Modelling). Later text will describe how BIM is defined in detail and what other tools and processes are available. The question is whether these tools are efficient or if they can be optimized. This will be analyzed with the help of this research, which is based on the information exchange literature review.

2.4.5 Method of information exchange

In the construction sector, known issues are in the fields of complexity, collaboration, concurrency and collocation (Jacob and Varghese, 2018). The question is whether a proper information exchange can help here.

To improve life cycle management of asset data and predictive analytics, certain platforms should be used for better management. Administration authorities are under tremendous pressure, because the effective management of highways does need appropriate processes. The road networks are aging and the number of users is increasing. From this, it can be concluded that maintenance and improvements of the highest standards are required. The vast growth in the last few years has led to different methods being used for handling all the information. A well-known method is Building

Information Modelling (BIM) (Brodt, 2013). It is said that, with the help of BIM, the design and construction phase can be used to inform all the different assets and registers in a project from an early point. An existing problem is that, when a project is crossing over from planning and building to the operation stage, a lot of information does get lost. Using BIM offers huge advantages, because in the road infrastructure sector a lot of different stakeholders are involved, they have to collaborate with each other, and what is happening is that at the same time a tremendous amount of data is produced. This needs to be managed and at the same time the goal needs to be that no information gets lost. To use BIM properly and become successful with it, the three parameters – people, process and technology – need to be combined (Aziz, Riaz and Arslan, 2017).

One of the reasons why road infrastructure projects are that complex is that, between a lot of different disciplines, different collaborations need to be involved. It is also a challenge to handle the pressure which arises in terms of performing in a concurrent mode. In mega projects, the different stakeholders who are involved are spread out globally and the team is not located at one specific place

This has led to the fact that the collaboration and the re-entrance of data in the handling of construction projects is becoming inefficient. Because of this, the idea is that a thorough information exchange can help. With regard to the information exchange, two questions need to be thought about: “Who needs to know what?” and “Should knowledge be shared between or after formal meetings?”

In road infrastructure projects, different stakeholders are involved, i.e. the project owner, the project manager and the steering group. The project owner is the key stakeholder and has the superior authority and responsibility for a successful project result. One of the project owner’s many tasks is to identify requirements and objectives and to determine the overall budget. Another term for the steering group is the management committee. This group represents the project owner in large project, when several owners are involved. This group is authorised to make decisions and can provide resources (Terje Karlsen, 2010).

Knowing this, it is helpful to understand why information needs to be shared and how it can be shared. First of all, it is important to say that, to be successful in a project, the access to data and information is mandatory. Information sharing plays a significant role in improving performance. The requirements for improved performance are a clear information sharing policy and a proactive approach to sharing information. Based on this, the most important factor for the participants to

share information is trust. The impact of commitment and the reciprocity is also an important factor which needs to be mentioned here (Zaheer and Trkman, 2017).

It is worth mentioning that an information exchange process does bring a lot of advantages to projects. It does help in increasing the existing knowledge, because of the participants past experiences. With such a process, upcoming challenges and issues in the existing project can be responded to more quickly. It also provides a simple way of sharing ideas and insights. In summary, it can be said that sharing information can avoid repeating mistakes and reinventing the wheel every time (Cyr and Wei Choo, 2010).

Many actors are involved in road infrastructure projects. This does mean that a lot of information needs to be shared. The challenges which arise are that information gets lost, that the interpretation of the data is wrong, and that the information which should be shared does not have a structure or is all stored in different locations. Another issue which is faced is that information and knowledge exchange is limited among life cycle phases. Where we are with the information exchange at the moment and what tools are used commonly? Although we are in the period of Industry 4.0, the information and knowledge exchange is mainly based on documents and 2D drawings. The literature research shows that that information management and the method of communication in the whole life cycle of a project is inefficient in a lot of projects so far (Hoeber and Alsem, 2016). Problems which are faced in current projects are that several stakeholders use different tools and processes to proceed. The data which are delivered are often in an unstructured way and it is hard to analyse them. Looking at optimal information management, the strategy needs to start at an early stage in the whole process. It is also important to split the data into different categories (Aziz, Riaz and Arslan, 2017).

Together with this, a well-known term is the building information modelling (BIM). A study conducted in 2019 investigated the challenges between facility management and building information management with regard to the information exchange process. It was proved that such a platform can enable an information exchange between different data sources and the facility management systems. A problem in all existing projects is that the employees spend a huge amount of time in searching, sorting, validating and recreating information (Matarneh et al., 2019).

The reason why BIM is becoming more and more popular is that a better design quality can be achieved. In a project, normally different disciplines are involved, for example, planners, architects, civil engineers, mechanical or operation managers. Every group normally has its own

platform or system for the specific goals of the group. Because of that, problems arise in terms of data incompatibility or a lack of interoperability in the information or data exchange processes (Lai, Deng and Chang, 2019) .

Problems arising in the transportation infrastructure are not only associated with the finance.

This means that attention needs to be paid to the public and to the engagement of the public. It is said that the early engagement of public stakeholders is significant to project success. How the involvement of the public affects the effectiveness, sustainability and the utility of every single road infrastructure project has been investigated in a study by WojewnikFilipkowska et al. (2019). They found that the impact of all stakeholders at an early stage can improve and determine the early development of trust-building processes.

Vivaldini (2020) wrote that the reason for new processes is to improve the communication and information exchange between the different stakeholders to contribute in the planning and the operation and to create an instrument for historical data and data analysis.

2.4.6 Information feed and decision framework

Large projects, such as road infrastructure projects, are infamous for deterioration in the execution phase. Due to the information feed within a project, decisions are made by the project managers. These decisions have a considerable effect on the project delivery.

Based on this proposition, in a study conducted by Eweje, Turner and Müller (2012), two research questions were proposed:

“Which factors of information-feed supporting a project manager’s decision impact the strategic value delivered by megaprojects for the sponsoring organization the most?”

“How can the decision framework of the managers of megaprojects be enhanced?” (Eweje, 2012)

What was found in that study is that, if the relationship between the host communities is not good, this negatively impacts the overall performance. Another surprising result of the research was that the project manager’s decision is not influenced by the tenure practising of the profession, but by their idea of what senior management want. What is confirmed and represented is that a risk management system enhances the decision-making process of the project manager in terms of the value-creating decision (Eweje, 2012).

Back in 1994, it was suggested that ways of manipulating data had been found, leading to the fact that a system is needed that is applying a procedure in which resources and information are treated effectively and more securely (Robson, 1994).

2.5 The gap in the literature

One of the gaps within the road infrastructure sector identified by the literature review is the fact that until now, digitization is used little in the construction sector. This finding will be the base for all further research within the scope of this dissertation. According to Yunfei (2019), the little use of digitization leads to the situation, that not all information that are available are used effectively which results in a gap of knowledge and a lack of available information. As there is little data regarding digitization in general in the construction sector, there is also too little data in terms of the complexity of risks in construction projects. The little use of digitization results in having too little reliable data available and the main challenges of megaprojects are the poor, unreliable and spurious information that is exchanged. Another challenge which occurs are conflicts between the decision-making parties, the policy, the planning persons and the public (Flyvbjerg, 2007). Because of the challenge of unreliable information exchange, the method of information exchange management is used within the scope of this dissertation. Because of the known issues regarding the little innovation in road infrastructure projects, the topic for this research was laid out with a focus on the industry 4.0 and the principles of Block chain Technology.

It is known that it is a huge challenge and very complex to implement and manage innovation itself. But, because of this risk-averse culture that we are living in, benefits and great opportunities are lost on a constant basis. The reason for that is that in road infrastructure projects innovation is not used, like it is used in other projects. But it needs to be considered how innovation can appear in road infrastructure projects and how it can be captured and produced (Maghsoudi et al., 2016). The question arises whether we do have the same issues in the area of the project management sector as well. Do we have the problem that companies and customers do not trust the existing models and forms? Do we also need a decentralized system here?

2.6 Generating a framework for the present research

To understand the meaning of a theoretical framework, the section will start with an explanation of different types of frameworks and models.

A model is the result of a process of representing a real-world object or phenomenon as a set of logical, mathematical and computational concepts and equations. Contemporary scientific practice employs at least three major categories of models: concrete models, mathematical models and computational models. Simulation of a system is the operation of a model in terms of time or space, which helps analyze the performance of an existing or a proposed system.

A framework is an abstraction (purposefully arranged and interrelated concepts) in which a system providing generic functionality can be selectively changed by additional, purposely developed constituents, thus providing application-specific features and services. In a pragmatic view, a framework (a piece of software, a system, or an environment) is a platform for developing specific applications. It supports logical, functional, computational, interaction and application aspects.

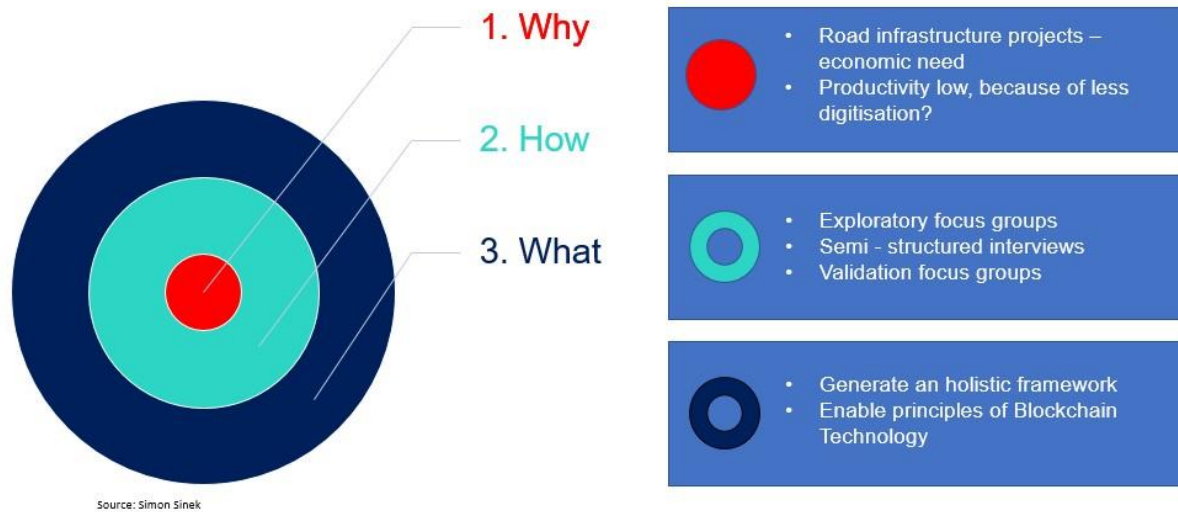


Figure 14 Understanding the why of the framework (own representation)

Simon Sinek (2014) mentioned in a speech that the most important is to understand the “why” of something and that it is important to understand “why” we are doing something before we can start thinking about the “how” and the “what”. For generating the framework, it is important to get an understanding why the framework needs to be developed.

Trust and communication are the themes that emerged in the literature review. Based on these themes, the idea is to generate a framework.

For solving the trust issue, the idea is to use the principles of BT and, for solving the communication issue, the method of the IET is used. But this is a result of the idea that communication and trust are not about the tool that they are more about the conversation, but tools are needed for communication and trust for having a good conversation. Thus, because of this, the idea is that a theoretical framework needs to be developed for this research.

Based on the literature review in this chapter, the motivation for the present research becomes clear. It is becoming visible that, from a medium and long-term perspective, a change in the

communication within road infrastructure projects is required. One possible solution for this can be an appropriate system that helps in the fields of transparency, traceability, immutability and trust. Basically, it can be supposed that implementing the principles of BT do make sense if:

Automation in a process is available

A process is repeatable several times a year and not only every four years

More than at least two stakeholders/different groups are involved

A value transfer is existing (not just monetary, for example information)

Information and documents need to be immutable (no manipulation)

Transparent processes are required

Trust is the foundation of a project/process (Shrier, 2020; Laurence, 2018; Lemieux, 2016; Clohessy and Acton, 2019)

Utilizing the principles of Block chain Technology for road infrastructure projects is essential and does need appropriate elaboration. The elaboration is based on the lack of information exchange management and the decision-making methods in the society and field of road infrastructure projects (Kahneman, 2012; Gyampoh-Vidogah, Moreton and Proverbs, 2003). Although we have arrived in the age of digitization, most of the documentation is still made on paper. This does make it hard for the exchange of information and documentation. The contribution of generating a holistic framework for bringing road infrastructure projects and the principles of Block chain Technology together, will require a lot of applications; nevertheless, it can provide benefits for the industry. The Block chain Technology is a breakthrough technology that is used in the meantime in a wide range of areas such as industries, banking and healthcare. Because of the special features of the technology it is essential to adopt it (Hames, 2022).

The relationship between the above exemplified aspects is illustrated in the conceptual framework for project management, road infrastructure projects, information exchange and principles of Block chain Technology in Figure 2-17. With the help of the arrows the relationship between the different areas can be understood.

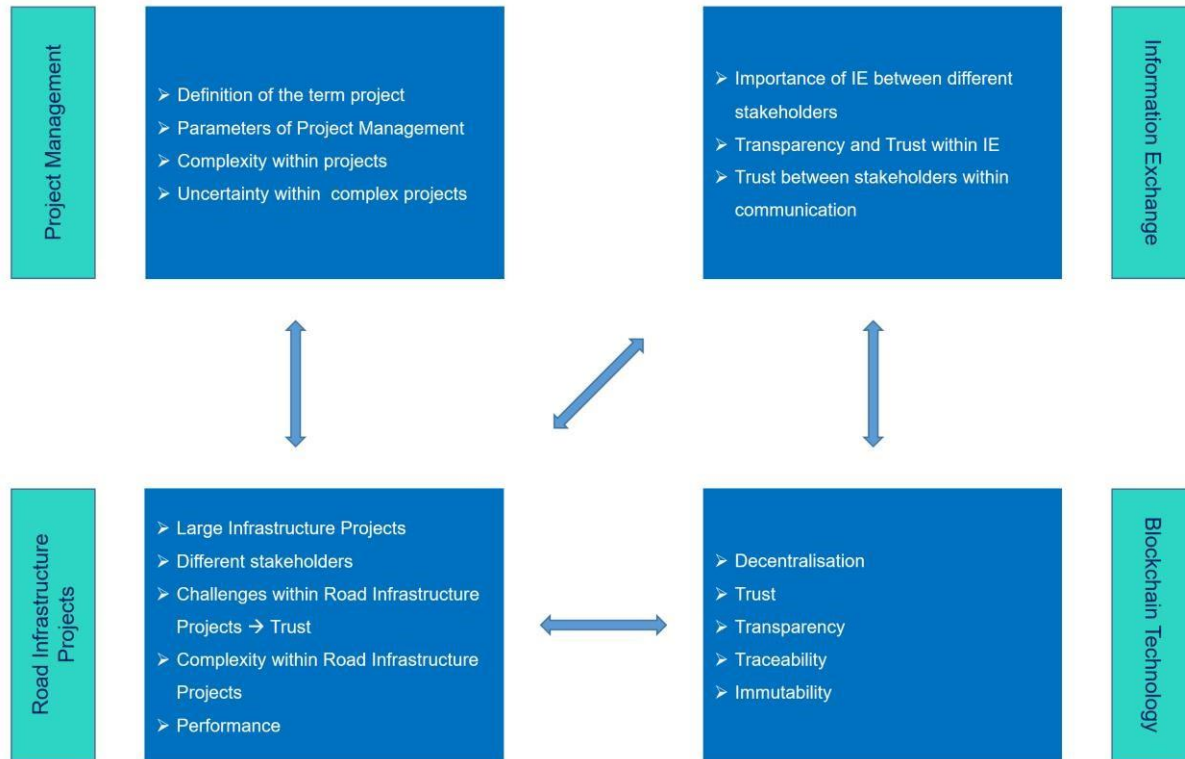


Figure 15 Conceptual Framework

2.8 Chapter summary

This chapter has investigated the theory and literature of project management, road infrastructure projects, Block chain Technology. The aim of the chapter was to provide a wide understanding of the current state of knowledge regarding the principles of Block chain Technology and in which fields this technology can be used in road infrastructure projects in relation to information exchange management. Trust is an issue within road infrastructure projects. Hence, the study so far demonstrates the importance of the implementation of a technology which enables us to increase the transparency and trust in a project. With the help of this literature review, the themes are addresses that will be investigated through the research. Based on this, the enablers and barriers for the present research were reviewed. An operating system can provide a number of advantages, with the help of Block chain Technology, interconnected with different stakeholders. Based on this, the development of a theoretical framework and the benefits of this were identified. In Conclusion, this chapter identifies the motivation for this study through demonstrating the enablers of the principles of Block chain Technology for road infrastructure projects.

Mobility needs to be strengthened, the economy should be treated with care and the growth should be secured. To ensure a working road infrastructure, investigations need to be made to have a future thinking regarding road infrastructure in every country. A working road infrastructure enables social participation, intelligence logistic and climate-friendly mobility. The problems that road infrastructure faces these days are too little budget, and mega- projects are time-consuming and, because of the over-complexity in planning projects, often lead to a standstill. Another problem which is receiving attention in road infrastructure projects is that many different stakeholders are involved in one mega-project. The problem with this is that they are all from different sectors and every sector is working differently. The literature review cleared up the fact that, for the above-mentioned reasons, many road infrastructure projects are being carried out inefficiently, but there are also positive examples. The question remains open as to whether the application of new technologies, such as BT, can make both efficient and inefficient projects even more successful.

With the help of the interviews conducted in the current research and the literature review about information exchange management, the idea is to develop the framework of a thorough information management process through the whole life cycle of project management. With regard to the principles of BT, the question is whether there will be a change in the way of working. Several barriers and challenges have to be overcome in terms of transparency, traceability and immutability, and what companies think about them. The statement which needs to be proved is that it is not only the technology that needs to be changed, it is also the cultural thinking and cultural change. Where we are in terms of a collaborative way of working and what can be optimized also need to be discovered. It is mandatory that a better information exchange management system needs to be thought about, not only to reduce failure costs but also to enhance the whole process in project management.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

In this chapter, the research design, the foundations for the research philosophies and the research methodology are laid out. To understand the choice of method, it is important to get to know which philosophy and approach is used. The end of this chapter will summarize which philosophy and method is used for generating the final research framework.

For the research itself, it is necessary to understand the different philosophical perspectives and the ones which are used for the present research. This helps in understanding and developing the current knowledge. It is also said that methods are secondary to the paradigm, which is defined as the basic belief (Creswell, 2013). With the research philosophy, important assumptions are made about the way the researcher views the world and about the way the results will be understood. The research philosophy helps in understanding how the researcher views the world. It helps to capture the inductive and deductive research and the ontological, epistemological and axiological perspectives. In the figure below, Saunders' research onion is visualised. This research onion includes the research philosophy, approaches, strategies, the method choices, and, in the inside, the techniques and procedures. To understand the onion, we have to start at the outside layer, which protects the inside layers. This whole research onion builds the foundation of the whole research methodology (Saunders et al., 2009, p.109).

The outside layers need to be peeled off to get from the outside to the inside.



Figure 16 Research onion (Saunders, 2009)

It can be said that the outer layer is the most important layer, because it points out and describes the way the researcher views the world.

3.1 Research Philosophy

The meaning of the word philosophy is love (philo) of knowledge (sophia) and it is used to announce the reflection of fundamental principles. Nowadays, it has become a concept of the body of knowledge and a chain of analytical skills (Brinkmann, 2018). The theoretical question is “What is the nature of reality?” (Brinkmann, 2018, p.7) and the practical one is “How should we act?” (Brinkmann, 2018, p.7). The philosophy is a huge area which does not focus on one special topic; the idea behind it is that, with questioning and a special approach, a special subject is being characterized. Substantial questions do arise in the field of philosophy (Saunders, 2009).

3.1.1 Positivism versus post-positivism

Positivism and post-positivism must be contemplated as philosophies used in science for scientific investigations. The two of them are to be considered as two independent philosophies. On the one hand the positivism emphasizes the importance of objectivity and the need to study observable components. On the other hand, the post-positivism is a philosophy that rejects positivism.

The worldview of the positivist is called the scientific method or doing science research (Creswell, 2009). Positivism is a direction in the philosophy that demands that findings which are supposed to have the character of knowledge should be limited to the interpretation of the 'positive', i.e. actual, sensually perceptible and verifiable findings. This line of thought can be found, in fact, in antiquity with the Greeks. The positivist is thinking that all knowledge is based on perception. True knowledge can only be gained through experimentation, and metaphysics is impossible for a positivist (Saunders, 2009). It is important to note that the approach of the positivist is that the real truth is nowhere to be found (Phillips and Burbules, 2000). To measure the social world of a positivist, an objective method should be used (Easterby-Smith et al., 2012). Following the statement by Rehmann and Alharthi (2018), positivism supposes that the truth subsists independently from humans and is nothing which is affected by human senses. Popper (1959) argues that humans will never be in a situation to obtain a general pledge. An example that philosophers often use is the example of the white swans. Although the result of an observation has been that all swans are white, it is not proved that all swans are white.

Post-Positivism emerged in the 20th century. In the post-positivism it is said that scientific thinking is similar to the common sense of humans. In contrast to positivist, post-positivists points out that it is not possible to rely on observations always. The post-positivism approach assumes that every method can have errors and that these errors can only be avoided if more than one method is chosen (Popper, 2002).

3.1.2 Realism

Making the hidden obvious is the strategy of realism (Brinkmann, 2018). The term realism encompasses a variety of philosophical positions, according to which phenomena independent of human consciousness exist which affect us, and which we can describe linguistically. Realistically, these are discussed with regard to very different phenomena, so that one speaks more precisely of realism with regard to a specific problem area. The understanding of realism is that something is recognized only with cognition (Saunders, 2009). Bhaskar (2008) brought forward the argument that no patterns are needed to make realism exist, because it exists independently from any structure. Hence, no experiments are needed to consider a condition and its consequences, made by humans (Easterby-Smith et al., 2002). Maxwell (2012) noted that critical realism is a combination of realist ontology with a constructivist epistemology. It can be said that, holistically, the world combines the characteristics that remain independent of humans with knowledge that is

built through human occupations. Hadot's (1981) understanding of realism is that realism is a special way of life and an existential attitude to it.

3.1.3 Interpretivism

Interpretivism is a "response to the over-dominance of positivism" (Grix, 2010, p.82). In interpretivism, the role of humans as social actors needs to be understood. For the interpretivism approach, the situations in which the researcher finds himself/herself need to be understood, which is essential for the position he/she takes (Taylor, 1985). The difference here is that the human is acting as an object, like a computer, or acting as a person. Interpretivism can be explained in relation to a play. Every actor plays a role in a play and acts in a way which can be interpreted by a human. To reflect this in real life, acts can be interpreted according to different meanings in life (Saunders, 2009). Mostly in interpretivism, researchers collect qualitative data over an extended period of time, such as through interviews and focus groups (Cohen et al., 2007). It can be concluded that interpretivism uses an inductive approach. The goal is to understand aspects with their correlations (Rehman and Alharthi, 2018). Gergen (1985, p.266) stated that "what we take to experience the world does not in itself dictate the terms by which the world is understood".

3.2 Research philosophies

When a piece of research is conducted, basically, there is no right or wrong. Also, the selected research philosophy significantly influences the relationship between the existing knowledge of the researcher and the procedure that is developed. In simplified words, the research philosophy is the way in which the researcher views the world (Saunders et al., 2012). Because of that, it is mandatory to give special attention to the research philosophy. Moreover, it is essential to ponder the chosen philosophical approach in terms of representing potential alternative approaches (Saunders et al., 2012).

In general, the research philosophy can be explained by two major adoptions, the ontological and the epistemological assumptions. To complete these two assumptions, the axiological, rhetorical and methodological assumptions need to be included in the research philosophy (Collis and Hussey, 2009).

To obtain an understanding about the five research philosophies, they are explained briefly as follows:

Ontology is concerned with the nature of reality (Saunders et al., 2012) Epistemology concerns what constitutes acceptable knowledge in a field of study (Saunders et al., 2012). Axiology is a

branch of philosophy that studies judgments about values (Saunders et al., 2012) Rhetoric is concerned with the language of research (Collis and Hussey, 2009) Methodology is concerned with the process of research (Collis and Hussey, 2009)

The ontology, epistemology and axiology are theoretical perspectives (Crotty, 1998). As Collis and Hussey (2009) mentioned, it is not possible to adopt these assumptions freely. They need to be given to other assumptions as well. The five mentioned perspectives will be explained below.

3.2.1 Ontology

Referring to the section above, “ontology is concerned with the nature of reality” (Saunders et al., 2012, p.130). The understanding of this is that the ontological assumption gives a general understanding about how the researcher views the world and the nature of research (Creswell, 2009). In the literature, a lot of different approaches can be found that explain the ontological assumptions. In the following sub-section, only the most important considerations will be explained. The question behind ontology and metaphysics is, “What can be said to exist and how?” (Brinkmann, 2018, p.7). Physics itself explains how different objects move through space and time. Ontology constitutes a deeper investigation in terms of what space and time finally are (Brinkmann, 2018). Starting out from Aristoteles, ontology is understood as the ‘first philosophy’. It is defined as: being (philosophical theology), the soul (psychology) and the context of all beings in the whole cosmology (Kunzman et al., 1991). The term ontology means the study of being. Saunders (2009) outlined that ontology is split into objectivism and subjectivism.

Bryman (2012) argued that, in the view of objectivism, social aspects appear independent of a social performer. Subjectivism is the opposite of that. In subjectivism, the social aspects arise from social performers and they are dependent on and are influenced by the awareness and the understanding of these. It is said that reality in the view of subjectivism is socially constructed.

The thinking behind ontology is the researcher’s view of the nature of reality or being. Both are able to be used in business and management research (Saunders, 2012). It also can be said that ontology relates to characteristics of the real world (Creswell, 2013). There are four different types of ontology:

Realism (the world has only one truth); it can also be said that the world can be discovered and be explained through the application of scientific methods. Internal realism (there is one truth, but this is not accessible); it is said that the activities of knowing of the humans creates what is known. Relativism (the world has many truths, but the truth is independent from the discovery process)

and Nominalism (the reality is created by humans (Smith et al., 2012). Nominalism can also be described as a ‘looping effect’, because it is said that interpretations are made by interpretations (Brinkmann, 2018).

3.2.2 Epistemology

The difference between epistemology and ontology is that ontology explains the “what” and the meaning behind epistemology is “what it means to know” (Crotty, 1998, p.10). Eldabi et al. (2002) noted that epistemology is related to the conviction about the way in which knowledge is constructed. In this conjunction, it can be said that knowledge is something which can be appropriated or is something which is based on personal experience (Burrell and Morgan, 1979). The epistemology is the doctrine of the condition, nature and limits of knowledge. The relationship between knowledge, subject, object and content is addressed. Epistemology deals with the preconditions and foundations of knowledge in the individual sciences. Its methods, principles, concepts and goals are clarified and subjected to critical examination (Kunzman et al., 1991). Epistemology describes the researcher’s view in terms of what constitutes acceptable knowledge (Saunders, 2009). In epistemology, a major difference between objectivist/positivist and subjectivist/constructivist is made (Crotty, 1998). The area of epistemology describes how knowledge is generated. Psychologists reject the idea that human thought and behavior can ever be studied objectively. They argue that there is no single objective reality. Rather, each of us constructs our own understanding and interpretation of ‘reality’ embedded in the context of our interactions with others. ‘Reality’ is therefore highly individual and subjective (Grieg and Taylor, 1999).

Similar to ontology, Saunders et al. (2012) and Bryman (2012) classify epistemology into four approaches: positivism, realism, interpretivism and pragmatism. Positivism assumes that only facts that can be observed can be used to obtain data and facts for a law. Saunders et al. (2012) noted that realism is a similar approach to positivism as there is a reality quite independent of the mind. Opposite to positivism and realism is interpretivism. In an interpretivist approach, the researcher needs to recognize the different interpretations of the different humans with their different roles in the society. This leads to the need to adopt a particular attitude to understand different situations and details in that reality. Last but not least is pragmatism, in which the most important determinate of the epistemology, ontology and axiology you adopt is in the research question (Saunders et al., 2012).

3.2.3 Axiology

Different to epistemology and ontology is axiology. Compared to epistemology and ontology, axiology is a relatively new research philosophy. This philosophy was applied in the twentieth century. Axiology investigates the issues which arise from the moment human beings begin to reflect on conditions of life, the structure of reality and the order of nature human beings are placed in (Hart, 1971). Axiology is the researcher's view of the role of values in the research. During the whole research, the researcher needs to highlight which value the view plays in all stages of the research (Saunders, 2009). This means that it can be said that the researcher is not forcing his/her view on people.

Regarding the axiological approach, it is considered that the researcher needs to be able to formulate their own values, as these are the foundations of the conclusions and deliveries of the research (Heron, 1996; Saunders et al., 2012).

Referring to the assumption that it is not possible to conduct a study completely value free, Bryman (2012) mentioned that because of the principle of objectivity, research, that is based on the positivist research philosophy, can be undertaken that is value free. With the exception of the value-free (positivism) philosophy all other philosophies are value-driven. According to Saunders et al., (2012) are the different philosophies value-driven to different degrees from the value-laden realism to the value-bound interpretivism.

3.2.4 Rhetoric

The meaning of rhetoric is the chosen language that is used to document a piece of research (Collis and Hussey, 2009). From a rhetorical perspective, it is mandatory that the language reflects the values and the choices philosophy involved in the research.

This significant meaning of the language can be seen when the formal style of research from a positivist perspective and research from an interpretivism perspective are compared. In an interpretivism study, a variable style is used and normally a first-person wording is used. In contrast, in positivism a passive style is used and it is free of the researcher's values (Collis and Hussey, 2009).

3.2.5 Methods

The method also plays a significant role in the whole research. Because of the importance of this, it will be reviewed in an extra chapter. The background of the methods is about the procedure

regarding how the whole research is undertaken (Saunders et al., 2012). Some of the methodological considerations are the methods, the research design and the time horizon.

The reason why the methodology is mentioned in this chapter as well is because the above stated philosophies have a significant impact on the chosen method. This can be explained with the following example mentioned by Collis and Hussey (2009). When for example a positive approach is chosen, concepts need to be used that will support the positive approach with the help of large samples. In the case of an interpretative approach, methods with small samples will be better.

3.2.6

Table 2 Philosophical assumption

Research philosophy	Understanding	Questions
Ontology	The ontology is the understanding of what is reality	• What is the nature of reality? • What is the world like?
Epistemology	The understanding of how the reality can be known	• How can we know what we know? • What is the considered acceptable knowledge? • What constitutes good quality data? • What kind of contribution to knowledge can be made?
Axiology	The understanding of values	• What is the role of values in research? • How should we treat our own values? • How should we deal with the values of research participants?

3.2.7 Philosophy of the researcher

The research philosophy which is used for the purpose of this study can be seen in ontology. As mentioned above, the ontology is split into four different types. Normally, the truth can be seen from a realism perspective, but in this research nominalism is used due to the fact that interpretations are made from interpretations. Nominalism says that there is not only one truth; the idea behind this is that people try to understand how everybody acts. So from subjectivism, humans obtain opinions from others and also get an understanding of different views and different behaviors. In this research, a subjectivist/constructivist approach is chosen.

This approach can be explained in that way because the researcher will use semi-structured interviews and make use of a questionnaire. Through this procedure, the researcher will obtain different views and opinions and will try to understand how every individual participant is acting. It also needs to be understood that the results will only be brought to the current research since the

study itself is not capable of conducting investigations with all the groups and stakeholders that are experts in this area.

3.3 Research approaches

As the different philosophies have been described and it has been explained which view the researcher will follow, in the next sub-chapter the several research approaches will be introduced.

3.3.1 Deductive

According to Saunders et al. (2019) a deductive approach is a suitable method when developing a research strategy to test hypotheses and is very objective in nature.

The research approach of deduction is also known as the testing theory. In this approach, a theory or hypothesis is developed and a design is created to test it, as illustrated in Figure 3-4 (Saunders, 2009; Brinkmann, 2018).



Figure 17 Deductive research approach

Braun and Clark (2006) mentioned that, in the deductive approach for the coding, a framework with the corresponding topics is used. The framework is usually structured with a start list (Miles and Hubermann, 1994), and, in the analysis of the data, it is expected that certain core capabilities will be included (Bradley et al., 2007). The deduction is using existing knowledge to test a hypothesis.

3.3.2 Inductive

On the other hand, the inductive approach is the building of theory (Saunders, 2009). The inductive approach refers to approaches that primarily use detailed readings of raw data to derive concepts and themes (Thomas, 2006). Curry et al. (2009) mentioned that in the inductive approach all data are analyzed section by section, and based on this data codes are collated to paragraphs and section of texts. Through this procedure, the results and findings of a study different to deduction are gathered through the analysis of the data and not of the expectations of certain core capabilities (Thomas, 2006).



Figure 18 Inductive research approach

The goal in inductive research is that a structure is gathered through the data collection. Based on this gathered data, a theory can be developed (Rehman and Alharthi, 2018). In other words, the induction is going from a detailed analysis to general knowledge.

3.3.3 Abduction

Different to deduction and induction, abduction starts with a classification of something and makes the indeterminate more determinate to enable actions (Alvesson and Kärreman, 2011). Charles Sanders Peirce named this approach in 1934 as a supplement to deduction and induction (Van Maanen et al., 2007). Through the abduction approach, an understanding is developed for contingent situations to identify if a setting becomes more clear and convertible (Brinkmann, 2018). A five-step strategy was developed by John Dewey (1910/1991), which can be referred to as the abduction approach:

A real doubt is generated, because of an unresolved problem. The problem is particularized, as data is collected systematically about the given problem. The investigator sets a hypothesis to solve the problem.

This hypothesis is elaborated and compared to other possible solutions. Based on this, the effects of the proposed hypothesis are considered.

Lastly, the hypothesis is tested by an experiment, whether the problem can be solved through this hypothesis or not.

3.3.4 Research approach of the researcher

Related to the explanations in the previous sections the research approach for this work is the abduction. The abduction combines the deductive and the inductive approach. The reason for the combination is because with the help of the deductive approach an existing theory is used, a hypothesis will be developed that will be tested afterwards. With the help of this approach data will be collected and based on the collected data the final holistic framework will be created. The

way forward is explained in more detail by the following five (5) steps applied within the scope of this research.

The unresolved problem faced in this research is the fact that different stakeholders do not trust each other in road infrastructure projects.

The challenge with not trusting each other was supported by the results of the data collection conducted through the semi structured interviews and the administered questionnaire.

The hypothesis that was made through research is that the principles of the Block chain Technology can support in the challenge of not trusting each other in the field of information exchange.

The hypothesis is elaborated with the help of the creation of a theoretical framework in the current research work.

The hypothesis has not been tested yet, but this is mentioned in the chapter about limitations and in the recommendation for further works.

3.4 Research design

In a research study, a research design is needed. A research design is a technique for collecting, analyzing, interpreting and reporting the data gathered during the research. Different models are available for this. In this chapter, two models will be described and at the end the model that will be used by the researcher is defined. It is important to understand why a specific model has been chosen, because this will set the logic and will explain the interpretations at the end of the study. Saunders et al. (2012, p.159) stated that the research design is “the general plan of how you will go about answering your research question(s)”. In terms of the research design, the researcher also needs to make a decision about whether to choose a mono-method or a multiple method.

Basically, there are two different ways to conduct a piece of research (Bryman, 2012; Saunders et al., 2012). Quantitative research design which is based on a positivist research philosophy and a deductive research approach, usually numeric data are generated through a quantitative research design.

Qualitative research design which is based on an interpretivism research philosophy and an inductive research approach, normally non-numeric data are gathered through a qualitative research approach.

Based on the explanation of quantitative research and qualitative research, three models will be described, the multi-methods, the mono-methods and the mixed-methods (Creswell, 2009).

3.4.1 Quantitative research

When a quantitative study is undertaken, a clearly defined method is required. But the simplified definition from the beginning of the chapter does not meet the complexity of the mentioned research approach. According to Creswell (2009, p.4), a more detailed definition of quantitative research is:

“Quantitative research is a means for testing objective theories by examining the relationship among variables. These variables, in turn, can be measured, typically on instruments so that numbered data can be analyzed using statistical procedures. The final written report has a set structure consisting of introduction, literature and theory, methods, results, and discussion (Cresswell, 2008). Like qualitative researchers, those who engage in this form of inquiry have assumptions about testing theories deductively, building in protections against bias, controlling for alternative explanations, and being able to generalize and replicate the findings.”

A number of techniques have been developed to conduct quantitative research. Schwandt (2001) explained quantitative research as something that is described in an amount or a number. As quantitative research data is normally numerical, it is often used in statistics.

Another area where it is used is when different variables need to be compared with each other (Saunders et al., 2012). Normally, quantitative research has a logical and linear structure. Within this structure, analysis and measurements are made to identify the relationship of different data sets (Eldabi et al., 2002).

Quantitative research replicates the positivist approach, whereby a matter is presented scientifically or a result is an independently measurable characteristic. In quantitative research, a deductive approach is often used. With the help of collected data, the researcher is able to reflect if the results can be confirmed or should be disconfirmed. The goal of a quantitative study is to answer a specific question (Creswell, 2009).

Quantitative data is numerical data which helps to meet special objectives. For example, the data can be a range from simple counts, prices or rental costs. Quantitative data is often used in conjunction with random samples. Quantitative means all the data used for data collection technique and analysis procedures (Saunders et al., 2012).

Finally, it can be said that the content of quantitative research is the following (Cobin and Straub, 2008):

Linear research process

Standardized approach
Hypothesis testing
Representative samples
Explain, measure, behave
Measurements of variables

→ Experimental design

In conclusion, the impression is created that a quantitative approach can also be seen as an experimental design.

Relating to studies of construction project management, which is relevant to the topic of this research, Amaratunga et al. (20002a, p.22) mentioned the following strengths:

Comparison and replication are allowable

Independence of the subject observed by the researcher (observer)

Subject under investigation is objectively measured

Reliability and validity may be determined more objectively than in qualitative research

Strong in measuring in descriptive aspects; and emphasizes the need to formulate hypotheses for subsequent verification

Amaratunga et al. (2002a) also mentioned the weaknesses of quantitative research. From their perspective, this type of research only gives a short picture of a special situation and the disadvantage is that the meanings behind data and numbers are not analyzed in more detail.

3.4.2 Qualitative research

The use of qualitative research is a well-established approach. Traditionally, qualitative research has been assessed in studies in which flexibility is needed. The difference from quantitative research is that qualitative research refers to non-numeric data. One of the main goals of qualitative research is to obtain an understanding about the doings and saying of others (Schwandt, 2001). With the help of qualitative research, researchers are able to obtain new findings and understandings.

A more detailed definition of qualitative research is given by Creswell (2009) as a means for exploring and understanding the meaning individuals or groups ascribe to a social or human problem. The process of research involves emerging questions and procedures, data typically collected in the participant's setting, data analysis inductively building from particulars to general themes, and the researcher making interpretations of the meaning of the data. The final written

report has a flexible structure. Those who engage in this form of inquiry support a way of looking at research that honours an inductive style, a focus on individual meaning and the importance of rendering the complexity of a situation.

Porter (2007) noted that there are two ways of defining qualitative research. The first definition refers to a method that can be used to collect and analyze data, and the second one relates to the conjectures of epistemology and ontology. Basically, it is said that there is no clear definition about qualitative research found in the present literature (Creswell, 2009). A piece of qualitative research tends to be the result of an interpretivism approach; in that research, knowledge is generated through the intermediation between humans to make it more descriptive in nature.

Norman Denzin and Yvonne Lincoln defined qualitative research as a situated activity that locates the observer in the world. Qualitative Research consists of a set of interpretive material practices that make the world visible. These practices transform the world. They turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings, and memos . Other qualitative data are videos, questionnaire surveys, documents as (reports, meeting minutes, e-mails) or newspaper articles.

At this level, qualitative research involves an interpretative, naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to make sense of or interpret phenomena in terms of the meaning people bring to them” (Brinkmann, 2018, p.5). Qualitative data are all data which relate to non-numeric data. This data is more complex. Examples of qualitative data are data like interviews or policy documents (Saunders, 2009). The analysis of the data of a qualitative study is made through induction. It is noted that this research method is used as a tool, when a group or individuals attached to a social or human problem needs to be explored and understood (Creswell, 2009).

A typical qualitative research procedure is that multiple forms of data collection are used. In the present research, semi structured interviews and questionnaires will be used. Based on these collection forms, the researcher analyses and reviews the data, categorizes them and puts them into themes (Creswell, 2009). The important fact is the understanding of the content of the data. The researcher generally tries to understand the knowledge, values and beliefs in terms of the study (Bryman and Bell, 2011). The advantage of using this approach is that it is less structured than the quantitative approach, so it gives the participants more flexibility in their responses and it is possible to speak out on issues that appear to be important (Yauch and Steudel, 2003).

Mayring et al. (2007) argued that the qualitative approach includes the following parameters:

Circular research process

Open approach

Exploratory design

Small samples, case orientation

Understand, describe, experience

Interpretative paradigm

Constructive design

Compared to the quantitative approach, the qualitative approach can be seen as a constructive design.

3.4.3 Research choices

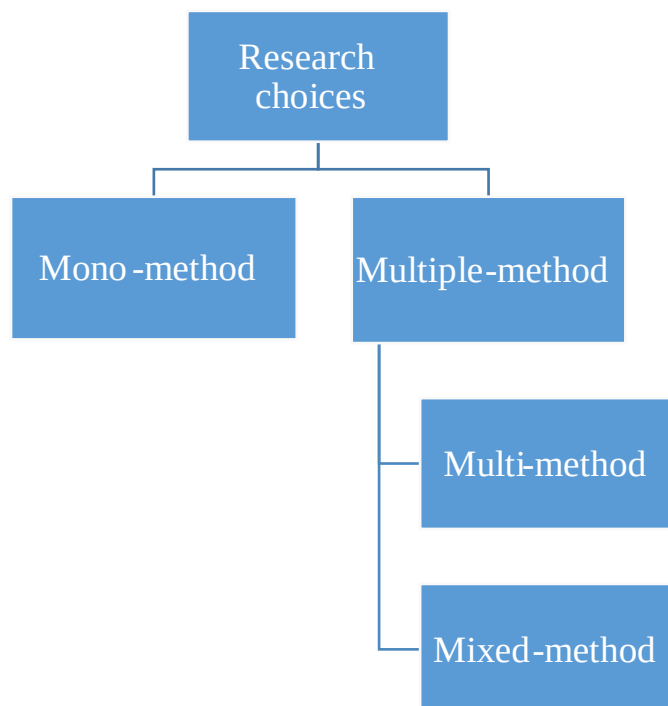


Figure 19 Research choices (Saunders, 2013)

For choosing a method for the study, it needs to be used a mono-method approach or a multiple-method approach. The mono-method approach comprises only one data collection technique with an appropriate analysis procedure (Saunders, 2009). Tasjakkori and Teddlie (2003) noted that using a multiple-method approach is reasonable, as the data will be trusted for answering the

research question. In the current study, a multi-method approach, using a qualitative approach, is chosen, which belongs to the multiple method, the multi methods and mixed-methods approaches are explained in the following chapters in more detail. For completeness, the section starts with a description of the mono-method.

3.4.4 Mono-method

Although the mono-method approach is not used in this study, it will be discussed for completeness. When a mono-method approach is chosen, only one data collection technique will be used and only one corresponding analysis procedure (Saunders, 2009). A study conducted in 2020 identified 127 articles to investigate which strategy was most often used – was it the multi strategy, the mixed strategy or the mono strategy? The study found that it was the mono strategy (Vizcarguenaga-Aguirre and López-Robles, 2020). The mono-method approach is classified into the simple mono-method approach and the complex mono approach. The main statement of the mono-method approach is that “one type of method is generally better than another” (Hassard and Pym., 1993, p.28). On the other hand, the argument of the complex mono-method approach is that “one type of method is better than another for the purpose of addressing a particular theoretical issue” (Hassard and Pym., 1993 p.28).

3.4.5 Mixed-method

A mixed-method is chosen when a qualitative and a quantitative study is executed in an experiment design. A mixed-method approach combines quantitative and qualitative data. It is a term from the Anglo-American debate on methodology in the social sciences and education, which has been used since the end of the 1990s. Specifically, since the publication of the monograph "Mixed Methodology" by Abbot Tashakkori and Charles Teddlie (1998), it has gained great prominence. Until the quantitative data is useful, it has to be analyzed using special techniques. With the help of charts and statistics, it is possible to describe relationships and trends within the collected data (Saunders, 2009). Mixed-methods approaches are known to be used when the philosophical assumptions have pragmatic knowledge claims. These approaches are sequential, concurrent and transformative. As already mentioned, it is not just a mixture of quantitative and qualitative data and analysis; it is also used when open- and closed-ended questions need to be answered and when emerging and predetermined approaches exist. The following practices are used by the researcher in a study when a mixed method approach is chosen:

Quantitative and qualitative data is collected

Data at different stages of the enquiry is integrated
Visual pictures of the procedures in the study are presented
The practices of qualitative and quantitative research are employed
(Creswell, 2009).

3.4.6 Multi-method

A research is called multi-method when the chosen method is focusing either on qualitative or on quantitative data (Collier, 2008). In the mixture of multiple methods, it is mandatory that more than one data collection procedure is used with links to analysis techniques (Tashakkori and Teddlie, 2003). In the current research, the chosen method is multi-method research and qualitative data will be used. Research using qualitative data is eclectic, leading to the statement that multi-methods are characterized in three different ways. One way is the relationship to interpretative and constructivist approaches. The second is because of the growing number of interconnections between qualitative and quantitative research tools, and the last is with regard to the increasing diversity of techniques focused on convention qualitative traditions (Collier, 2008).

Based on the considerations above an approach for the research needs to be identified. As the researcher wants to generate a holistic framework through the study, a multi-method approach is chosen. The methods that are chosen in the study are semi structured interviews and the questionnaire. With the two independent sources of data the methods will corroborate the research findings. The researcher wanted to establish how the principles of Block chain Technology can be utilized in the management of road infrastructure projects. In order to find an answer on this, the researcher decided that it is essential to choose two methods of the qualitative approach.

Analyzing in which fields the principles of the Block chain Technology in the life cycle of the project management can be used and digging deeper into the different phases and discussing the possibilities in more detail.

3.5 Researcher's decision

From the view of the researcher using participants that are directly working in the road infrastructure sector and who are involved in the related challenges every day, these two methods were the most valuable ones for this research. These two methods are the semi structured interviews and the questionnaire. This is also underlined by the thinking of the post-positivism approach which says that at least 2 methods need to be used, to make sure, that results are not falsified. Because of that the multi-method approach has been chosen.

3.6 Research strategy

There are a number of instruments available for gathering data in a piece of research. With the help of the research strategy, the researcher is able to answer the research question. Each available strategy is linked to a quantitative, qualitative or mixed-methods research design

(Saunders et al., 2012) posits that the research strategy is the methodological link between your philosophy and subsequent choice of methods to collect and analyze data. Creswell (2009) mentioned that over the last few years more strategies have become available for the analysis of data. Hence, only a number of the most common strategies will be explained in a compendious form in the following section.

3.6.1 Experiment

The reason for an experiment is to study etiological conjunctions. An example of this is that sometimes it needs to be investigated “whether a change in one independent variable produces a change in another dependent variable” (Hakim, 2000, p.98). A study regarding an experiment is conducted systematically in a laboratory setting to obtain an understanding of the relationship of different parameters to each other (Collis and Hussey, 2009).

3.6.2 Survey

Normally, a survey is associated with quantitative research, regarding questionnaires or structured interviews. The purpose of this approach is to examine patterns (Bryman, 2012). Saunders et al. (2012) argued that normally this research type is used in deductive research and is really popular in the field of business management research, as it is possible to collect a large amount of data with this approach.

3.6.3 Ethnography

Ethnography is a holistic study and normally uses qualitative methods. Ethnography is used when groups in their natural setting need to be studied over a period of time. The aim of the ethnography approach is to describe and interpret the shared patterns such as behavior, language and beliefs of a group of interacting individuals (Creswell, 2013). It is important in this approach that the cultural group of individuals has to be studied as an intact group in its natural setting (Creswell, 2009). This requires often extensive participant observations, trust from the participants, and a strong strategy to deal with the fact of being a researcher and being involved in the social life of the participants (Saunders, Lewis and Thornhill, 2012).

3.6.4 Phenomenological research

In this type of study, it is significant to gather meanings and insights into the meaning of the social phenomena. The phenomenology approach identifies and holistically understands the meaning of human experience as described by the research participants (Amaratunga et al., 2002; Creswell, 2009). In this light, phenomenology sees social phenomena as socially constructed, and is particularly concerned with generating meanings and gaining insights into those phenomena (Saunders, Lewis and Thornhill, 2007).

Phenomenology builds on the work of the German philosopher Edmund Husserl (1859-1938) from a philosophical perspective as well as the work in social phenomenology of the Austrian social scientist Alfred Schütz (1899-1959) (Schwandt, 2001; Outhwaite, 2003). Furthermore, it must be pointed out that the German philosopher Georg Hegel earlier argued that phenomenology would refer to “knowledge as it appears to consciousness” (Moustakas, 1994, p. 26).

According to Moustakas (1994), phenomenology studies a phenomenon as it appears to individuals in their consciousness. Moustakas (1994) further argued that the “very appearance of something makes it a phenomenon”, and any phenomenon can be the start of a study (p. 49). This approach is commonly used in qualitative research (Amaratunga et al., 2002; Creswell, 2013), which aims to identify, deeply understand, explain and describe a common or shared subjective experience of several individuals in terms of a phenomenon (EasterbySmith, Thorpe and Lowe, 1991; Schwandt, 2001; Creswell, 2013). This description, then, is different to explanations of analyses and keeps as much originality as possible and results in, e.g., “ideas, concepts, judgement and understanding” (Moustakas, 1994, p. 52).

However, phenomenologists are further concerned with delivering a reinterpretation, new and fuller meaning, while looking at a phenomenon from new perspectives and, most importantly, questioning the current meanings. Hence, phenomenology is characterized by objectivity and as a critical approach that “calls into question what is taken for granted” (Crotty, 1998, p. 83). Phenomenological studies usually consist of data collected from individuals who have experienced the phenomenon, which then will be analyzed to extract the meaning and the essence of collected experience in order to describe the phenomenon (Moustakas, 1994). Consequently, this approach is best suited for studies that seek to develop practices, policies and deeper understanding of a phenomenon through experiences of it that are shared by several individuals (Creswell, 2013).

3.6.5 Researcher's decision

According to Popper (2002) the post-positivism approach suggests that every method can have errors and that these errors only can be avoided, if more than one method is chosen (Popper, 2002). The multi-method research design for this work will be implemented utilizing two different research strategies. In a first step, semi structured interviews will be conducted with several engineers and senior managers from the Department of Roads. With the first data collection of conducting semi structured interviews, the foundation for the basic knowledge and understanding will be laid. This will help to meet objective 1. Based on this, in a second step, data will be collected with the help of questionnaires. The questionnaires will help in meeting the other objectives.

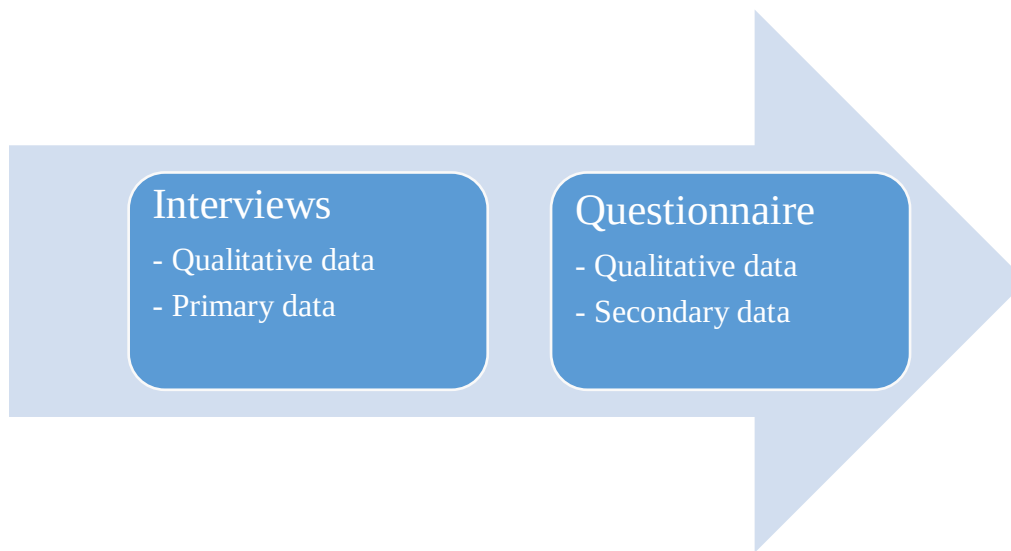


Figure 20

3.7 Time horizon

One mandatory part of the research design is the time horizon. At the beginning of the research, the time horizon that will be used for the data collection needs to be considered. Normally, two time horizons are differentiated. In simple terms, whether the research will take place in a particular time or over a given period with a series of data collection needs to be considered. The decision about this depends on the research question. The two different time horizons will be explained below:

3.7.1 Cross-sectional studies

A cross-sectional study is chosen when the research needs to be undertaken, for example in a special time frame. Through this study, data is gathered in different contexts to obtain a variety of

special cases to a special point of time. This study of the time horizon is often used when the time is constrained or resources are limited. An example of when a cross-sectional study is used is when it needs to be explained how factors or parameters are allocated in different organizations. The challenge with this study is that sometimes it is hard to select appropriate sample sizes, and explain based on these samples the existing phenomena under that study from the factors and give an explanation for the reasons for possible correlations. An advantage of a cross-sectional study is that it is inexpensive and an end is foreseeable, because the time frame is limited. A cross-sectional study is often used in a qualitative approach. In a lot of research, interviews are conducted over a special period of time (Bryman, 2012; Collis and Hussey, 2009; Saunders et al., 2012; Robson, 2002; Easterby-Smith et al., 2008).

3.7.2 Longitudinal studies

A longitudinal study is normally used when in a study, change or a development needs to be studied. An example of a longitudinal study is the UK television series “Seven Up”. In this series, the progress of a group of people was charted every seven years. With the help of this study, the researcher was able to gather a rich set of data that helped in developing theories about the development of humans (Adams and Schvaneveldt, 1991).

With the help of this example, it is understood that the data gathered through a longitudinal study is from the same group that is questioned several times over a long time period. This kind of study is normally used when time is not constrained and when the change or the development of a phenomenon needs to be investigated. The challenge of this study is that the research normally runs over a long period of time. Normally, these studies are time consuming and expensive (Bryman, 2012; Collis and Hussey, 2009; Saunders et al., 2012).

3.7.3 Researcher’s decision

For the present research, a cross-sectional study is chosen. This type of study is chosen because of the available resources for the work and the time constraint that is connected with this type of study. During the study, no change to or development of the collected data is expected.

3.8 Ethical considerations

Study ethics are the acceptability or suitability of the researcher's behavior with respect to the rights of the respondents and other study subjects, according to Saunders, et al. (2019). The

participants were afforded the chance to get clarification of the procedure before the researcher collected the data, and once they were satisfied, the interview preceded.

Permission to conduct the study at the Department of Roads was requested from the Bindura University of Science education and permission was also sought from the authorities at the Department of Roads to enable participants to ascertain the genuineness of the research before they could participate.

3.8.1 Informed consent

In this study, the consent to participate was first sought from the possible participants (people, community leaders and the school authorities. Levine (2014) holds that “informed consent is the voluntary agreement of an individual, or his or her authorised representative, who has the legal capacity to give consent, and who exercises free power of choice, without undue inducement or any other form of constraint or coercion to take part in research”. It allowed the creation of good rapport and full cooperation of the participants and this in the end allows objective gathering of data in a free, relaxed environment. Before taking part in the study, each participant was alerted of its purpose and objectives and their verbal agreement was obtained.

3.8.2 Non coercion

According to Endacott (2004), a researcher ought not to ever coerce someone to take part in research. The possible participant has the rights that includes the right to withdraw at any moment in time without penalty. This principle of non- coercion was strictly followed. All the participants were told by the researcher that they are free to withdraw from the research at any given time. Furthermore, no participant was given any financial nor non-financial benefit for participating, but they were thanked verbally for participating.

3.8.3 Protection from harm

The research must also make it a point to protect the participants from any form of harm. Qualitative interviews can be on a very sensitive topic that could cause emotional damage to a participant. Expecting such risks as well as those other risks from outsiders is key. In this study, the area is politically charged with emotions evoked in the recent August 23-24 elections and witch hunting for political enemies was rife. The researcher ensured that the participants avoided harm through the careful selection of participants.

3.8.4 Anonymity and confidentiality

Anonymity and Confidentiality are other ethical issues arising from the possible exposure of classified or restricted information such as the revelation of names or addresses or even the physical location of a certain respondent. The researcher ensured that such information revealed by any of the participants is safeguarded from unauthorised observation. All information is held in strict confidentiality. To ensure anonymity and confidentiality even considering the face-to-face interviews, no original names were included in the final document, but participants' rights and identities will be protected by using pseudonyms, for example, "Participant 1" as opposed to "Mr. X".

3.9 Chapter summary

To understand the shape of the investigation, the research approach and philosophical perspective of the current researcher need to be understood. The goal of qualitative research is the development of new theories or hypotheses. Normally, this approach is conducted through a couple of special individual cases, which are chosen by the researcher. The evaluation of the data happens through an abductive procedure. On the other hand, quantitative research aims to test existing theories or hypotheses. As the researcher wants to generate a holistic framework, in other words a new thesis or hypothesis will be formed, for enabling the principles of BT for managing road infrastructure projects, a qualitative research method with an abductive procedure is chosen. From an ontological point of view, the researcher is using the nominalism approach due to the fact that interpretations are made from interpretations. Thinking in an ontological approach, the research uses the thinking of a subjectivist/constructivist, because the foundation of the knowledge is generated based on individual sciences. With the help of a qualitative approach, semi structured interviews and questionnaires will be utilized. Finally, it can be said that a multi-method approach is chosen.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND INTERPRETATION OF FINDINGS

4.0 Introduction

The previous chapter ended with the explanation of the research strategy for the holistic framework that needs to be developed through the dissertation. The holistic framework is the final goal of the whole research. This chapter will define the techniques used to collect the data for the research at hand. As a multi-method research approach with qualitative data is chosen in the current research, the collection of qualitative data will be explained in more detail in the section on research methods.

Chapter 3, on the research methodology, discussed the philosophy, methodology and research choices that need to be made when a research design is constructed. As described in the above chapter, it is mandatory for the researcher to understand why a special philosophy and methodology were chosen. Either is it a qualitative approach or a quantitative approach.

The two research methods differ in their target intention. While qualitative research aims to gain deep insight and a comprehensive understanding of the research subject, quantitative research aims to examine large amounts of material. As the researcher's study is in the field of an area in which little research has been conducted so far, the most important thing is to gather deep insight and, because of that, qualitative research, in the form of semi-structured interviews and a questionnaire was chosen.

As within the chapter on research methodology, existing tools and methodologies are adopted in the current chapter, and a detailed discussion will be developed regarding the chosen research method based on the research question in this study. Hence, the chapter provides a step-by-step guide through the data collection and data analysis process, dealing with the logic around the research choices that were made.

Although the research question has already been mentioned in the introduction chapter, it is repeated here to keep in mind what will be answered at the end of the dissertation based on the literature review, the conducted semi-structured interviews and the questionnaire. The research question that has been developed and should be answered in this master's dissertation is:

“How Can the Principles of Block chain Technology Be Utilized for Improving Road Infrastructure Projects?”

So that the research question can be investigated in a structured way, the following aim and objectives have been synthesized. With the help of these aims and objectives, a defined approach is predetermined.

To identify in which aspects of managing projects the principles of Block chain Technology can be effectively utilized. To explore the interrelation between the mechanisms of the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects. To appraise the barriers to and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects. To develop a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects.

The purpose of the initial research objective is to consider that, with the help of semi structured interviews and the questionnaire and based on the conducted literature review, an answer will be found regarding the stage of digitization in which the construction industry stands in the era of industry 4.0. The principles of Block chain Technology are used as the technology in industry 4.0. Based on this, the question will be answered which beneficial parameters of Block chain Technology can be effectively used in the process of project management in the field of road infrastructure projects. Research Objective 2 builds on Research Objective 1 and addresses the topic through a combination of the literature review and the collected data through semi structured interviews and the questionnaire. The semi-structured interviews were conducted with both experts in the field of road infrastructure and in the area of Block chain Technology. The third research objective, expands on research objective 2 and will discuss the barriers to and the enablers of the principles of Block chain Technology. This will also be investigated with the help of semi-structured interviews and the questionnaire. Finally, with the research aim, a holistic framework for the implementation of the principles of Block chain Technology to support the management of road infrastructure projects will be developed.

4.1 Selected research strategy

This section provides an account of the data collection method in this study. In this section, an overview is generated that describes the methods that will be utilized in the research. For collecting the qualitative data, a multi-method research type was chosen. The techniques that are chosen for this master's dissertation are to conduct semi structured interviews and use of a questionnaire. Both methods have specific advantages and with the help of both methods a notable result is expected (Morgan, 1996).

4.1.1 Participant information sheet and consent form – data collection

Before the researcher was able to start collecting the data, the participants needed to be informed about the procedure. It is mandatory for the participants to be given an understanding of how the data will be treated and what will happen during the data collection, and about the research itself, and it is also significant for them to understand what will happen with the data when the research is finished.

In order to identify the participants for the semi-structured interviews and the questionnaire, the potential participants were asked to study the *participant information sheet* that was provided by the researcher. If they agreed with the information on the participant information sheet, they were requested to accept and sign the provided *consent form*.

The *participant information sheet* is structured into the following sections:

It is explained, with which methods the researcher will conduct the study. The purpose of the study is explained with the help of the research objectives. The participants are informed why they have been invited to the study and if they have to take part. In terms of the anonymity and confidentiality, it is described what will happen if the participants take part. The procedure of the recording of the data collection is explained. The possible disadvantages or risks from taking part are clarified together with the possible benefits of taking part in the study.

The participants are informed about how the data they provide will be treated and that taking part in the study is kept confidential.

One of the last sections defines what will happen to the results of the study and who the study will review. So that the participants feel confident, what will happen if something goes wrong is also explained.

Also, a data protection notice is mentioned with contact details for further information.

Both the researcher and the participant have a copy of the consent form. If the procedure of the participant information sheet was read by the participant and the consent form was signed, the researcher was able to start conducting the semi-structured interviews and the questionnaire.

4.1.2 Data handling and storage

After the researcher obtained the signed consent form, the semi-structured interviews and administration of the questionnaire were conducted.

The procedure in general was similar for both instruments. The researcher gave an introduction into the research, conducted the semi-structured interview and administered the questionnaire, transcribed these data and finally analyzed the data with the help of thematic analysis.

To guarantee participant anonymity, every participant was given a special code by the researcher. Thus, the anonymity of the participants is preserved through the whole research and also when the research is finished.

4.2 Response rate

The study adopted the response rate formula by Saunders, Lewis and Thornhill (2019) which expresses response rate as the proportion of successfully completed instruments relative to the total number of instruments distributed. Table 1.1 presents the response rate on the two instruments.

Table 3 Response rate Source: Primary data (2023)

Instrument	Distributed	Successful	Response rate
Interview Guide	10	9	90%
Questionnaire	240	220	92%
OVERALL	250	229	92%

The results presented in Table 1.1 shows that the response rate on the questionnaire was 92%, since 220 out of the 240 distributed questionnaires were successfully returned. In addition, a total of 9 interviews out of the 10 scheduled interviews were successfully carried out. This gave a response rate of 90%. According to Shirley and Sushanta (2018), a response rate of at least 70% is highly representative of the sample used. The overall response rate on all the instruments was 92%. This means that the overall response rate of the study was high enough to render the results representative of the study population.

The interviewees of the study had the following profiles as indicated in Table 1.2.

Table 4 The interviewee profiles (N = 9) Source: Primary data (2024)

Respondent	Level	Department	Gender
Interviewee 1	Chief Research Officer	Information Technology	Female
Interviewee 2	Chief Engineer, Construction	Construction	Female
Interviewee 3	Chief Engineer, Maintenance	Maintenance	Male
Interviewee 4	Deputy Director, Operations	Roads	Male
Interviewee 5	Chief Accountant	Finance	Female
Interviewee 6	Director, Information and Technology	Information Technology	Male
Interviewee 7	Deputy Director, Procurement	Procurement	Female
Interviewee 8	Deputy Director, Policy	Legal	Male
Interviewee 9	Chief internal Auditor	Audit	Male

From the results presented above, out of the 9 interviewed employees at the Department of Roads, 5 were managerial, and the remaining 4 were from the civil engineering field. This implies that the responses of the study were balanced in terms of the area of study, as there was a balance between the responses from those with managerial power and those with technical power. Having a balanced view was regarded as a plus in terms of representativeness of the population, as guided by Bordens and Abbott (2018).

4.3 Background information of respondents: Questionnaires

This section looks at the background information of the respondents, which determined the suitability of the participants in the study.

4.3.1 Gender of respondents Questionnaires

This subsection looks at the gender of the respondents. The gender was regarded as important in terms of the balance between the views of both genders when it comes to block chain technology in road infrastructure improvement.

Probably the knowledge of block chain technology in road infrastructure do differ with gender. The first sub sections present data for respondents from questionnaires followed by that from the interviews.

4.3.1.1 Gender of questionnaire respondents

Figure 4.1 presents the results on the gender of the questionnaire respondents.

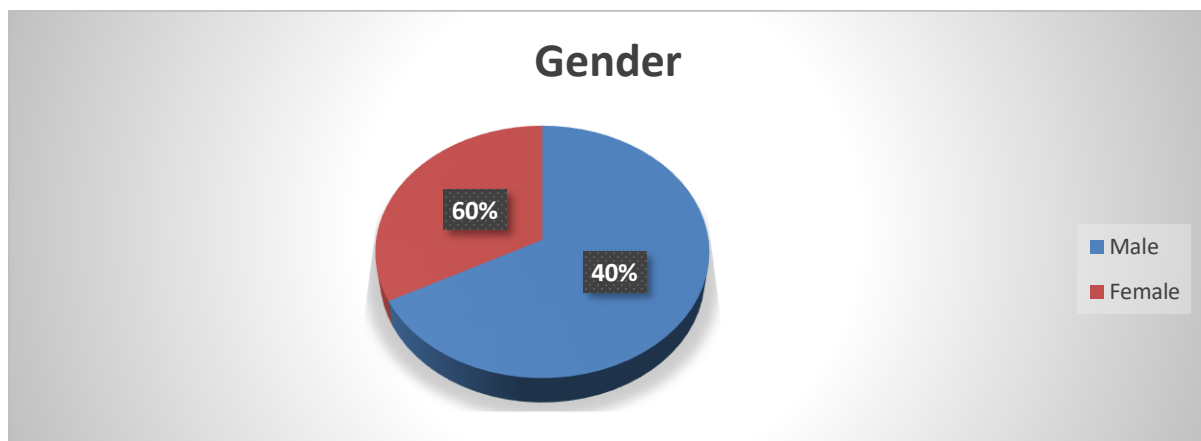


Figure 21 Gender of the questionnaire respondents (N = 220)

Source: Primary data (2024)

The results in Figure 3-3 indicate that 60% of the respondents were male, and the remaining 40% were female. Although there were more males than females who participated, all the gender categories were presented in the study. This implies that there was some balance in terms of the views and experiences of different respondents as affected by gender. The fact that the sample was constituted of both genders improves credibility and representativeness of the sample, in tandem with Barrick, Thurgood, Smith & Courtright (2020).

4.3.1.2 Gender of the interviewee respondents

The results on gender of the interview respondents are presented in Figure 3-4.

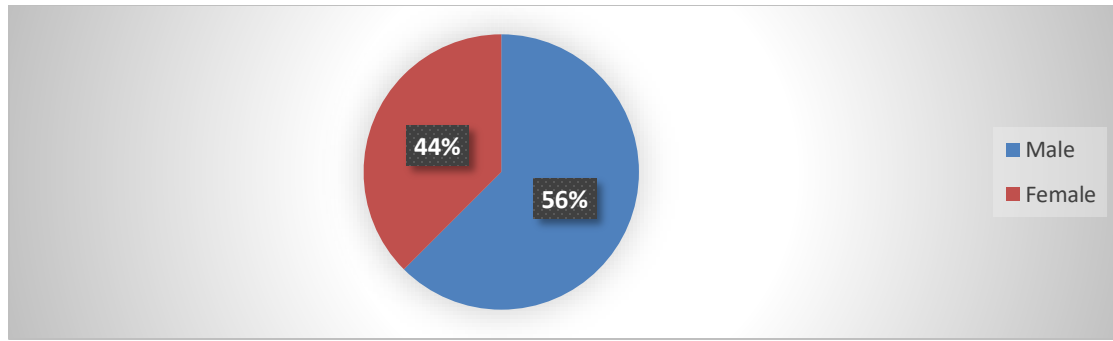


Figure 22 Gender of interview respondents (N = 9)

Source: Primary data (2024)

The results in Figure 3-4 indicate that 56% of the respondents were male, and the remaining 44% were female. Although there were more males than females who participated, all the gender categories were presented in the study. This implies that there was some balance in terms of the views and experiences of different respondents as affected by gender. In tandem with Barrick, Thurgood, Smith & Courtright (2020), the inclusion of both genders improved the representativeness of the results.

4.3.2 Age of respondents

Age was regarded as an important factor which can naturally moderate or mediate the knowledge of block chain technology in road infrastructure, as highlighted by Markos & Sridevi (2020) who highlighted that age of respondents can be a significant contributor to experience and expectation differences among individuals and groups.

4.3.2.1 Age of questionnaire respondents

The age of the questionnaire respondents is presented in Figure 3-5.

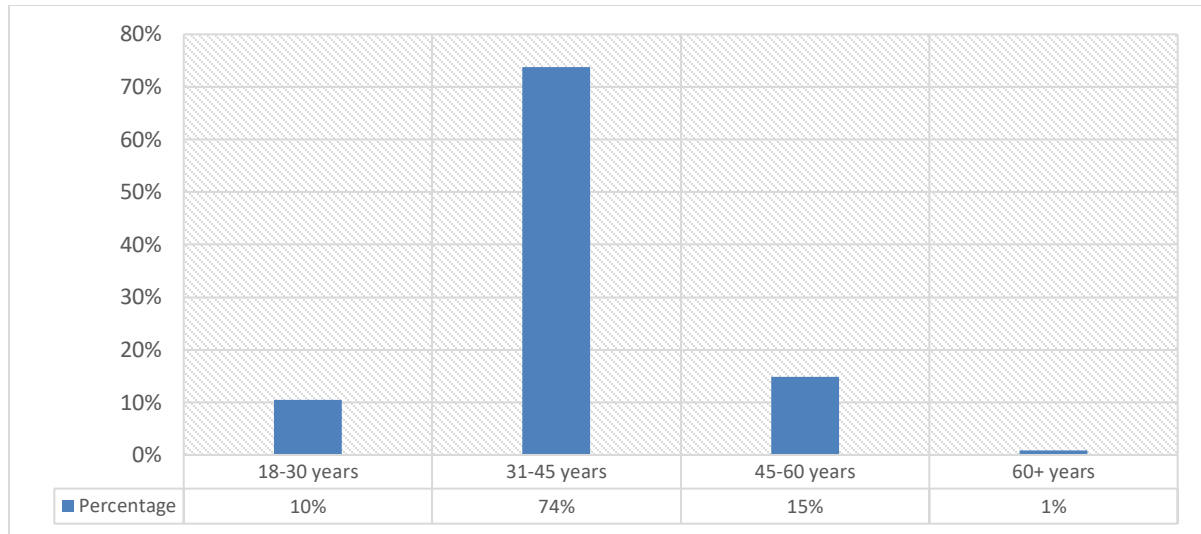


Figure 23 Age of the questionnaire respondents (N = 220)

Source: Primary data (2024)

From Figure 4.3, it can be noted that the majority of the questionnaire respondents are aged between 31-45 years with 74%, which is middle age group. This is followed by the 45-60 years group with 15% of the respondents. The least category is constituted of those who are 60+ years. The age is almost normally distributed. In this study, all age groups were represented, hence some balance in the results was enhanced, which implies improved results representativeness, in line with the arguments by Markos & Sridevi (2020).

4.3.2.2 Age of interview respondents

The results on the ages of the interview respondents are presented in Figure 3-6.

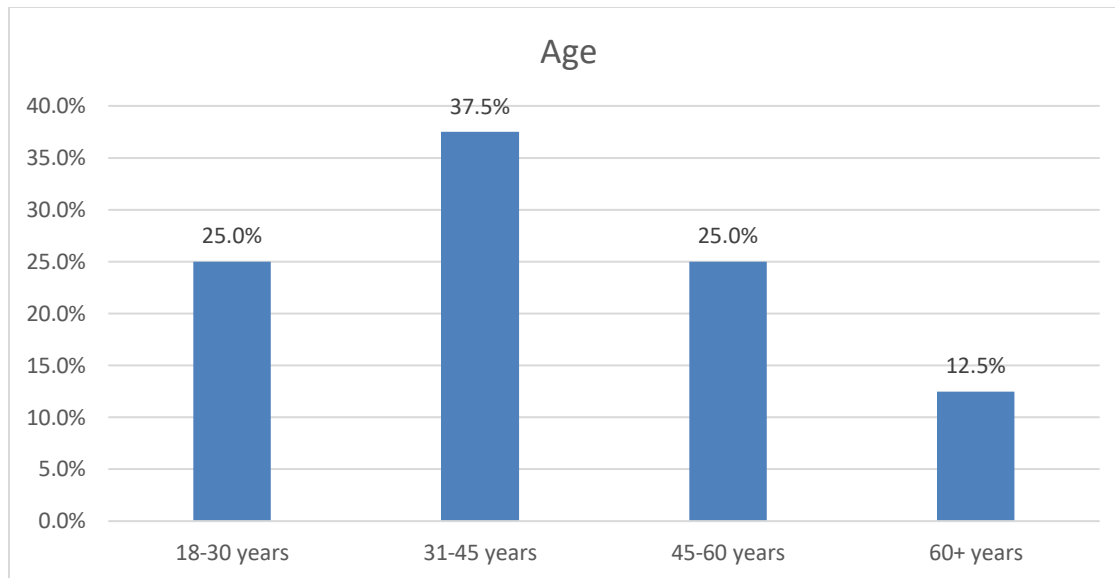


Figure 24 Age of interview respondents (N = 9)

Source: Primary data (2024)

From Figure 3-6, it can be noted that the majority of the interview respondents are aged between 31-45 years with 37.5%, which is middle age group. This is followed by both the 45-60 years and '18-30 years' groups, each with 25% of the respondents. The least category is constituted of those who are 60+ years. The age is almost normally distributed, with slight positive skewness. In this study, all age groups were represented. Basing on the arguments by Markos & Sridevi (2020), having a balance in respondent age groups also improves representativeness of the results.

4.4.3.0 Marital Status of respondents

Depending on someone's marital status, the knowledge of block chain technology to improve road infrastructure may have varying impact from the perspective of a different person, in line with Methode, et. al. (2019)'s argument.

4.3.3.1 Marital status of questionnaire respondents

The results on the marital status of the questionnaire respondents are presented in Figure 4.5.

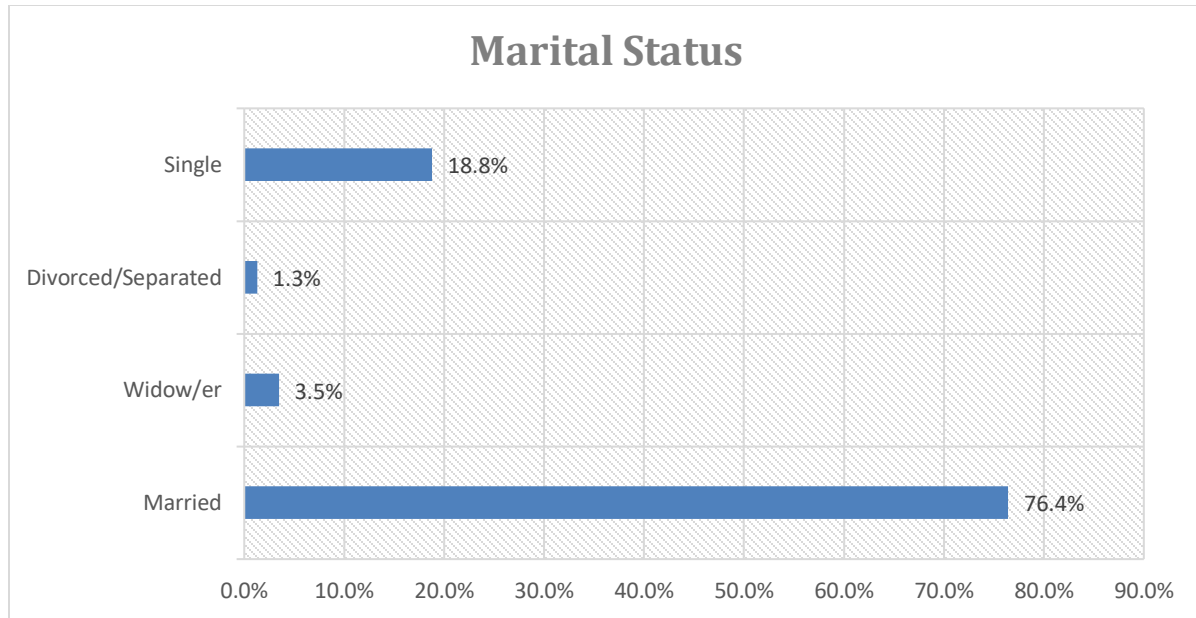


Figure 25 Marital Status (N = 240)

Source: Primary data (2024)

The results in Figure 25 show that the modal marital status is ‘married’, which constitutes 76.4% of the respondents, with the least being those who are divorced or separated (1.3%). Although the status is inclined more to those who are married, all the statuses are represented, which implies that all marital statuses were represented in the sample, hence the study was able to collect and process data from any type of employee in terms of marital status. The notion is that the marital status, family and life responsibilities of a person can impact on how they think or how they are actually affected by the implementation of block chain technology to improve road infrastructure, in line with the arguments by Methode, et. al. (2019).

4.3.3.2 Marital status of respondents of interview respondents

The marital statuses of the interviewee respondents are presented in Figure 3-8.

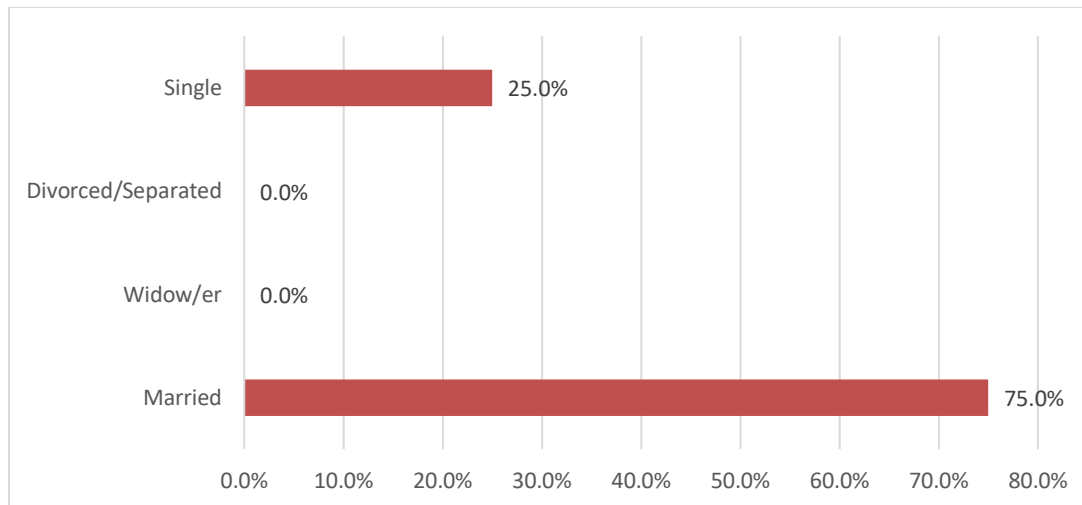


Figure 26 Marital status of the interviewees (N = 9)

Source: Primary data (2024)

The results in Figure 26 show that the modal marital status is ‘married’, which constitutes 75.0% of the respondents, and the rest are single (25%). Although the status is inclined more to those who are married, there are also those who are single, which implies that there are some variations in the marital statuses in the sample, hence the study was able to collect and process data from any type of employee in terms of marital status. The notion is that the marital status, family and life responsibilities of a person can impact on how they view the implementation of block chain technology to improve road infrastructure and also how they think or how they are actually affected by the implementation of block chain technology to improve road infrastructure in line with the arguments by Methode, et. al. (2019).

4.3.4 Experience levels of respondents

The levels of experience with the organization may bring different views to the implementation of block chain technology to improve road infrastructure, as argued by Idowu, Ibietan & Joshua (2020).

4.3.4.1 Experience levels of questionnaire respondents

The subsection presents the results on the experience levels of the questionnaire respondents with the Department of Roads as presented in Figure 27.

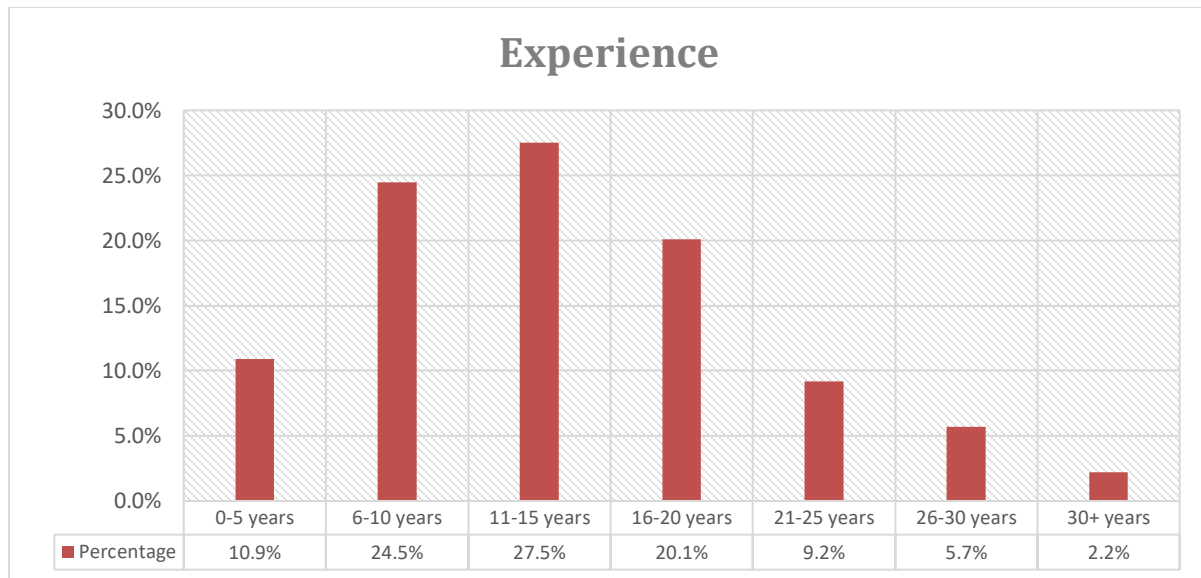


Figure 27 Experience levels of questionnaire respondents with the Department of Roads (N = 240)

Source: Primary data (2024)

The results show that the majority of the questionnaire respondents have had 11-15 years (27.5%), followed by 6-10 years (24.5%), with the least being made up of those with 30+ years (2.2%). The distribution shows some slight positive skewness, implying that lower levels of experiences are dominant than higher levels of experience. Overall, 89.1% of the respondents have had at least 6 years of experience with the Department of Roads, implying that the study generally collected data from those who have high experiences with the Department of Roads, who are better able to relate the events at the Department of Roads for a longer period. Thus, they are more able to tell if block chain technology can be implemented to improve road infrastructure in the Department of Roads, given known trends and past experiences (facts). This enhances the credibility of the results in terms of representativeness. This is in tandem with the arguments by Idowu, Ibietan & Joshua (2020).

4.3.4.2 Experience levels of interview respondents in the Department of Roads

The subsection presents the results on the experience levels of the interview respondents with the Department of Roads as presented in Figure 28.

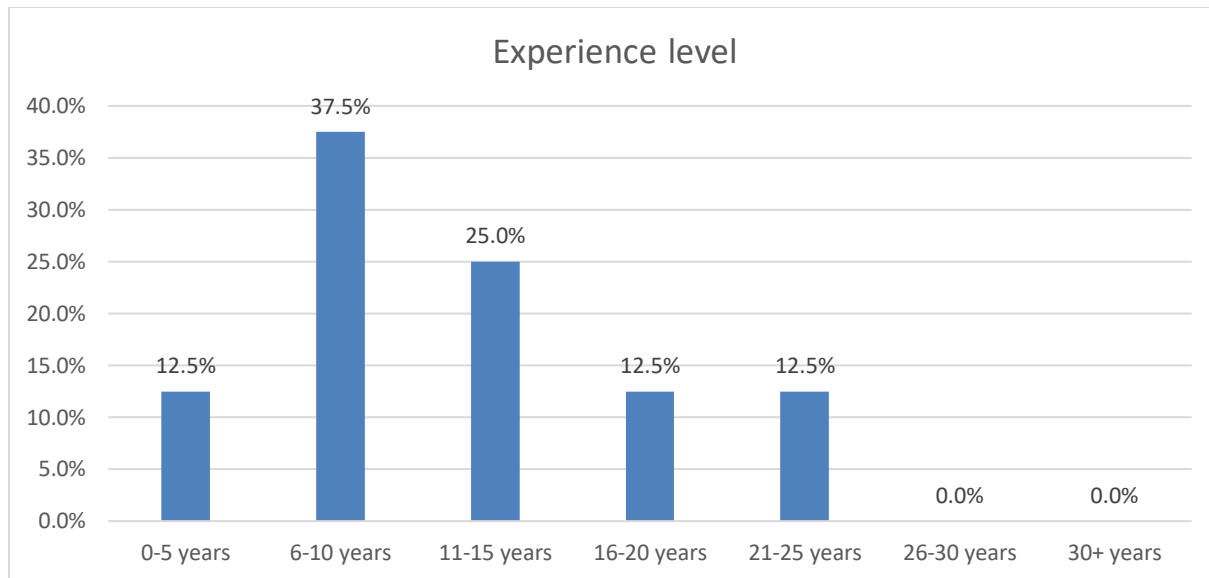


Figure 28 Experience levels of interview respondents with the Department of Roads (N = 9)

Source: Primary data (2024)

The results show that the majority of the interview respondents have had 6-10 years (37.5%), followed by 11-15 years (25.0%). The distribution shows some slight positive skewness, implying that lower levels of experiences are dominant than higher levels of experience. Overall, 87.5% of the respondents have had at least 6 years of experience with the Department of Roads, implying that the study generally collected data from those who have high experiences with the Department, who are better able to relate the events at the Department of Roads for a longer period. Thus, they are more able to tell if block chain technology can be implemented as a way of improving road infrastructure, given known trends and past experiences (facts). This is consistent with the arguments of Idowu, Ibietan & Joshua (2020).

4.4.5 Examining in which aspects of managing road infrastructure projects can the principles of Block chain Technology be effectively utilized in the Department of Roads.

The first objective of the study sought to examine areas in which the aspects of the principles of Block chain Technology can be effectively utilized in managing road infrastructure projects in the Department of Roads. This was sought for in order to understand the current status the Department has implemented block chain technology. Questions were asked in both the questionnaire and the

interview guide as the instruments of the study. Table 4.3 presents results on the questionnaire respondents with regards to the statement, and Table 4.5 presents results on the responses from the interview guide.

4.4.5.1 Examining in which aspects of managing road infrastructure projects the principles of Block chain Technology can be effectively utilized in the Department of Roads

The results in Table 5 show that the responses from the questionnaire respondents on how the Department of Roads has implemented block chain technology in road infrastructure improvement.

Table 5 Examining in which aspects of managing road infrastructure projects the principles of Block chain Technology can be effectively utilized in the Department of Roads (N = 220)

Project Transparency and Tracking	Budget and Financial Management	Stakeholder Engagement and Public Communication	Project Performance and Monitoring	Risk Management and Fraud Prevention
44	60	20	46	50
20%	27%	9%	21%	23%

Source: Primary data (2024)

From the results above, 20% of the respondents indicated that the principles of Block chain Technology in managing road infrastructure projects can be effectively utilized in the Department of Roads through Project Transparency and Tracking, 27% of the respondents indicated that the principles of Block chain Technology in managing road infrastructure projects can be effectively utilized in the Department of Roads through Budget and Financial Management , 9% of the respondents indicated that the principles of Block chain Technology in managing road infrastructure projects can be effectively utilized in the Department of Roads through Stakeholder Engagement and Public Communication , 21% of the respondents indicated that the principles of Block chain Technology in managing road infrastructure projects can be effectively utilized in the Department of Roads through Project Performance and Monitoring, the remaining 23% of the respondents indicated that the principles of Block chain Technology in managing road infrastructure projects can be effectively utilized in the Department of Roads through Risk Management and Fraud Prevention. All in all, the questionnaire respondents generally were in

strong agreement that the Department of Roads needs to implement block chain technology in managing road infrastructure (220/220 or 100% of the respondents were in agreement). The finding here was that the principles of Block chain Technology can be effectively utilized in the Department of Roads in various aspects of managing road infrastructure projects.

Table 6 Interviewees' responses on Examining in which aspects of managing road infrastructure projects can the principles of Block chain Technology be effectively utilized in the Department of Roads. (N = 9)

Respondent	Response
Interviewee 1	Allows various parties to access and update a shared ledger
Interviewee 2	Leads to cost savings in road infrastructure management
Interviewee 3	It ensures environmental sustainability is crucial in For large-scale road projects
Interviewee 4	Allows the implementation of smart contracts
Interviewee 5	Protects against fraud and errors and ensuring that all project documentation remains trustworthy and accessible
Interviewee 6	Allows tracking and storing all transaction records over time making it ideal for auditing purposes
Interviewee 7	Enables faster and more secure transactions
Interviewee 8	Ensures that data is tamper-proof and auditable
Interviewee 9	Reduces administrative overheads, mitigate delays, and enhance operational efficiency, thereby improving project delivery

Source: Primary data (2024)

From the interviews conducted, as presented in Table 6, Interviewee 1 highlighted that “Block chain’s decentralized nature allows various parties to access and update a shared ledger. In complex road infrastructure projects, there are typically many stakeholders, each with different interests.” Interviewee 2 said “The use of block chain could lead to cost savings in road infrastructure management.” Further, Interviewee 3 highlighted that “For large-scale road projects, ensuring environmental sustainability is crucial.” Interviewee 4 had to say “Block chain allows the implementation of smart contracts, which are self-executing contracts with predefined terms.” Interviewee 5 had this to say “This would protect against fraud and errors, ensuring that all project documentation remains trustworthy and accessible”. Interviewee 6 highlighted that

“Block chain’s ability to track and store all transaction records over time makes it ideal for auditing purposes.” In addition, Interviewee 7 highlighted that “Block chain enables faster and more secure transactions. This will be ideal to the Department”. Interviewee 8 had this to say, “The security features of block chain, such as encryption and decentralized verification, ensure that data is tamper-proof and auditable”. Lastly, Interviewee 9 had this to say, “This could reduce administrative overhead, mitigate delays, and enhance operational efficiency, thereby improving project delivery.”

4.4.6 Extent of belief that there are interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects

The second objective of the study was to ascertain extend of the belief that there are interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects. The questionnaire respondents were asked to indicate the extent to which they believe that there are interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects, as the justification for the perceived extent of interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects in the Department of Roads.

The results are presented in Table 4.4.

Table 7 Exploring the interrelation between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects (N = 220)

Least Extent	Less Extent	Moderate Extent	Larger Extent	Largest Extent
0	0	46	104	70
0%	0%	21%	47%	32%

Source: Primary data (2024)

The results in Table 7 show that a total 0% of the respondents highlighted that they believe there are no interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects to the least extent, 0% again highlighted that they believe there are no interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects to less extent, 21% highlighted that they believe there are interrelations between the principles of Block chain Technology and the performance of

Managing Road Infrastructure Projects to the a moderate extent, 47% highlighted that they believe there are interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects to a larger extent, and 32% highlighted that they believe there are interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects to the largest extent. The results reveal that the Department of Roads employees somewhat appreciate the interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects , the majority are clear of the interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects or they do see the interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects .

4.4.6.1 Justification for indicated interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects

The respondents were asked to justify the extent which they believed there are interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects.

100 respondents answered:

‘Block chain’s decentralized nature allows various parties to access and update a shared ledger. In complex road infrastructure projects, there are typically many stakeholders, each with different interests. Block chain can foster better collaboration by providing a single, transparent source of truth that all parties can refer to. This is also a way to improve communication, coordination, and alignment between government agencies, contractors, and suppliers, thus enhancing overall project performance’.

120 respondents answered:

‘Block chain technology is inherently transparent due to its decentralized and immutable ledger. I believe that incorporating BCT into road infrastructure projects would improve the accuracy and availability of project data (e.g., budget tracking, timeline updates, quality assurance records). This transparency fosters trust among stakeholders (e.g., contractors, government agencies, and the public), ensuring accountability at each project stage.

The interviewees were also asked the same question on interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects, and they generally concurred with the findings from the questionnaire.

4.4.6.2 Interviewees' responses on exploring the extent of interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects

The interviewees were asked to indicate the extent of interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects. The results are presented in Table 8.

Table 8 Interviewees' responses on exploring the extent of interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects (N = 9) Source: Primary data (2024)

Respondent	Response
Interviewee 1	Block chain's decentralized nature allows various parties to access and update a shared ledger. In complex road infrastructure projects, there are typically many stakeholders, each with different interests.
Interviewee 2	The use of block chain could lead to cost savings in road infrastructure management.
Interviewee 3	For large-scale road projects, ensuring environmental sustainability is crucial.
Interviewee 4	Block chain allows the implementation of smart contracts, which are self-executing contracts with predefined terms.
Interviewee 5	This would protect against fraud and errors, ensuring that all project documentation remains trustworthy and accessible.
Interviewee 6	Block chain's ability to track and store all transaction records over time makes it ideal for auditing purposes.
Interviewee 7	Block chain enables faster and more secure transactions. This will be ideal to the Department
Interviewee 8	The security features of block chain, such as encryption and decentralized verification, ensure that data is tamper-proof and auditable
Interviewee 9	This could reduce administrative overhead, mitigate delays, and enhance operational efficiency, thereby improving project delivery.

From the interviews conducted, as presented in Table 4.5, Interviewee 1 highlighted that “Block chain’s decentralized nature allows various parties to access and update a shared ledger. In complex road infrastructure projects, there are typically many stakeholders, each with different interests.” Interviewee 2 said “The use of block chain could lead to cost savings in road infrastructure management.” Further, Interviewee 3 highlighted that “For large-scale road projects, ensuring environmental sustainability is crucial.” Interviewee 4 had to say “Block chain allows the implementation of smart contracts, which are self-executing contracts with predefined terms.” Interviewee 5 had this to say “This would protect against fraud and errors, ensuring that all project documentation remains trustworthy and accessible”. Interviewee 6 highlighted that “Block chain’s ability to track and store all transaction records over time makes it ideal for auditing purposes.” In addition, Interviewee 7 highlighted that “Block chain enables faster and more secure transactions. This will be ideal to the Department”. Interviewee 8 had this to say, “The security features of block chain, such as encryption and decentralized verification, ensure that data is tamper-proof and auditable”. Lastly, Interviewee 9 had this to say, “This could reduce administrative overhead, mitigate delays, and enhance operational efficiency, thereby improving project delivery.”

4.4.7 To assess the barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads.

The third objective of the study sought to assess the barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads.

. This section presents results on this assessment.

4.4.1 Questionnaire responses on the assessment of barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads

The results in Table 9 show the responses from the questionnaire respondents on the assessment of barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads.

Table 9 Assessment of the barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads (N = 220)

No Effect	Less Effect	Moderate Effect	Big Effect	Huge Effect
0	1	58	100	61
0%	0.5%	26%	45.5%	28%

Source: Primary data (2024)

From the results above, 0% of the respondents indicated that there is no effect of barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads , 0.5% indicated that there is less effect of barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads , 26% indicated that there is moderate effect of barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads, 45.5% have indicated that there is big effect of barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads , and the remaining 28% have indicated that there is huge effect of barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads. More have indicated big effect than less effect. All in all, the findings are that there is big effect of barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads.

4.4.7.1 Justification for the indicated perceived big effect of barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads

The questionnaire respondents were asked to justify why they indicated their respective perceived large effect of barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads.

The results are summarized in this subsection.

160 respondents highlighted that:

The barriers that include high costs, lack of expertise, resistance from stakeholders, regulatory challenges, and security concerns can be a hindrance to the implementation of this technology. These challenges must be addressed to maximize Block chain's potential in transforming road infrastructure management.

60 respondents highlighted that:

Without enablers for Block chain adoption in road infrastructure projects such as government support, technological readiness, skilled workforce, clear regulations, and the demand for transparency, it will be difficult to implement the technology. These factors can foster a favorable environment for Block chain integration.

From these results, the respondents have generally conformed that there is effect of barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads 4.3.4 Interviewees' responses on exploring the extent of interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects

The interviewees were asked to assess the barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads. The results are presented in Table 4.5.

Table 10 Interviewees' responses on assessing the barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads (N = 9)

Respondent	Response(Barriers)	Response(Enablers)
Interviewee 1	Limited funding or budget allocation for technology innovation	Government support or incentives
Interviewee 2	Fear of failure or reluctance to experiment with new technologies	Technological readiness (existing infrastructure)
Interviewee 3	Insufficient awareness or understanding of block chain's benefits	Skilled workforce and expertise in Blockchain
Interviewee 4	Integration challenges with existing systems	Stakeholder collaboration and buy-in
Interviewee 5	Concerns about data privacy and security	Clear regulatory frameworks
Interviewee 6	Lack of regulatory framework or unclear policies	Proven success in pilot projects or similar industries
Interviewee 7	Resistance to change from stakeholders	Enhanced security and data integrity
Interviewee 8	Lack of technical expertise or knowledge	Public demand for more transparent and efficient infrastructure projects
Interviewee 9	High implementation costs	Improved project tracking and real-time updates

Source: Primary data (2024)

From the interviews conducted, as presented in Table 10, Interviewee 1 highlighted that limited funding or budget allocation for technology innovation is a barrier whilst government support or incentives is an enabler

Interviewee 2 said fear of failure or reluctance to experiment with new technologies was a barrier whilst Technological readiness (existing infrastructure) was the enabler. Further, Interviewee 3 highlighted that insufficient awareness or understanding of block chain's benefits acts as a barrier

whilst skilled workforce and expertise in Block chain acted as an enabler. Interviewee 4 said integration challenges with existing systems is a barrier and stakeholder collaboration and buy-in acts as an enabler Interviewee 5 highlighted concerns about data privacy and security as a barrier and a clear regulatory framework as an enabler

Interviewee 6 highlighted that lack of regulatory framework or unclear policies was a barrier and a proven success in pilot projects or similar industries as the enabler. In addition, Interviewee 7 highlighted that resistance to change from stakeholders was the barrier whilst enhanced security and data integrity are the enablers. Interviewee 8 highlighted lack of technical expertise or knowledge as the barrier and public demand for more transparent and efficient infrastructure projects as the enabler. Lastly, Interviewee 9 said high implementation costs is the barrier whilst improved project tracking and real-time updates is the enabler

4.5.6 To develop a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects.

The fourth and final objective of the study sought to develop a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads.

This section presents results on this assessment.

4.5.8.1 Questionnaire responses on the development of a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads.

The results in Table 11 show the responses from the questionnaire respondents on the development of a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads.

Table 11 Need for development of a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads. Table 4. 6: (N = 220)

No Need	Less Need	Moderate Need	Large Need	Huge Need
0	2	40	58	120
0%	1%	18%	26%	55%

Source: Primary data (2024)

From the results above, 0% reflected that there is no need for development of a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads , 1% reflected that there is less need for development of a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads, 18% reflected that there is moderate need for development of a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads , 26% reflected that there is large need for development of a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads , and the remaining 55% which constitutes the highest percentage reflected that there is large need for development of a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads. More have indicated large need than less need. All in all, the findings are that there is a large need for development of a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads.

4.5.8.2 Justification for the perceived need for development of a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads.

The questionnaire respondents were asked to justify why they perceived a need for the development of a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads.

The results are summarized in this subsection.

171 respondents highlighted that:

The framework for the utilization of Block chain technology in road infrastructure projects aims to streamline project management, enhance transparency, and improve communication among stakeholders. The key enablers include government support, technological readiness, stakeholder collaboration, and a skilled workforce. These components contribute to a successful implementation by ensuring a clear strategy, secure data handling, and integration with existing systems.

However, there are notable barriers such as high initial investment, lack of technical expertise, resistance from stakeholders, regulatory challenges, and concerns about data privacy. Overcoming these barriers requires strategic planning, pilot testing, regulatory alignment, and effective stakeholder engagement.

49 respondents highlighted that:

The development of this framework should focus on creating a roadmap for phased implementation, specifying roles for each stakeholder, and setting clear metrics to measure success.

The interviewees were asked to assist in developing a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads. The results are presented in Table 12.

Table 12 Interviewees' responses on developing a framework for the utilization of Block chain Technology to support the management of Road Infrastructure Projects in the Department of Roads (N = 9)

Respondent	
Interviewee 1	Block chain has the potential to drastically reduce project risks by ensuring that milestones are met as agreed upon. This could improve the overall success rate of road projects and create a better public image for the department

Interviewee 2	Block chain provides a secure environment for data because once it is recorded, it cannot be tampered with. This is particularly important for projects with multiple contractors and stakeholders, where you need to ensure the integrity of the records
Interviewee 3	Block chain technology is still emerging, and while it shows great promise, it's important to evaluate its compatibility with the department's current systems. It would require initial research and planning to decide which block chain framework suits our needs
Interviewee 4	Block chain technology could also be expanded to include smart cities projects. By utilizing block chain in road infrastructure, we could tie it into larger initiatives that involve urban planning, public transportation, and environmental sustainability
Interviewee 5	Block chain technology requires high computational resources, so scalability might be an issue, especially in large projects with numerous transactions. Moreover, the department needs to ensure compliance with data protection laws when dealing with sensitive project information
Interviewee 6	Block chain can help streamline communication. Instead of relying on separate documents and emails, the decentralized ledger can serve as a single source of truth, helping contractors and subcontractors stay aligned with each other, and reducing the chances of miscommunication
Interviewee 7	A block chain-based system would provide an easy-to-access audit trail for every transaction, making it easier to justify project expenditures. This could also help in resolving disputes by offering concrete proof of actions, payments, and agreements
Interviewee 8	Block chain will significantly improve efficiency by automating contract execution through smart contracts. For example, payments could be automatically triggered when certain project milestones are verified. This minimizes delays and ensures timely payments to contractors and suppliers
Interviewee 9	It could create a system where every phase of a road project is tracked, from planning and budgeting to completion. If we have a decentralized ledger,

	every stakeholder will have access to the same information, eliminating misunderstandings and dispute
--	---

Source: Primary data (2024)

From the interviews conducted, as presented in Table 4.5, Interviewee 1 highlighted that Block chain has the potential to drastically reduce project risks by ensuring that milestones are met as agreed upon. This could improve the overall success rate of road projects and create a better public image for the department. Interviewee 2 said Block chain provides a secure environment for data because once it is recorded, it cannot be tampered with. This is particularly important for projects with multiple contractors and stakeholders, where you need to ensure the integrity of the records. Further, Interviewee 3 highlighted that Block chain technology is still emerging, and while it shows great promise, it's important to evaluate its compatibility with the department's current systems. It would require initial research and planning to decide which block chain framework suits our needs. Interviewee 4 said Block chain technology could also be expanded to include smart cities projects. By utilizing block chain in road infrastructure, we could tie it into larger initiatives that involve urban planning, public transportation, and environmental sustainability. Interviewee 5 highlighted that Block chain technology requires high computational resources, so scalability might be an issue, especially in large projects with numerous transactions. Moreover, the department needs to ensure compliance with data protection laws when dealing with sensitive project information. Interviewee 6 highlighted that Block chain can help streamline communication. Instead of relying on separate documents and emails, the decentralized ledger can serve as a single source of truth, helping contractors and subcontractors stay aligned with each other, and reducing the chances of miscommunication. In addition, Interviewee 7 highlighted that a block chain-based system would provide an easy-to-access audit trail for every transaction, making it easier to justify project expenditures. This could also help in resolving disputes by offering concrete proof of actions, payments, and agreements. Interviewee 8 highlighted that Block chain will significantly improve efficiency by automating contract execution through smart contracts. For example, payments could be automatically triggered when certain project milestones are verified. This minimizes delays and ensures timely payments to contractors and suppliers. Lastly, Interviewee 9 said it could create a system where every phase of a road project is tracked,

from planning and budgeting to completion. If we have a decentralized ledger, every stakeholder will have access to the same information, eliminating misunderstandings and dispute.

4.6 Presentation of Instruments validity

Cronbach's Alpha assessed the internal consistency of questionnaire. It measured how related a set of items are as a group, and is commonly used in social science research. The value of Cronbach's Alpha has a maximum of 1, with higher values indicating greater internal consistency. The reliability of the questionnaires was tested using the Cronbach's Alpha, using SPSS. Table 13 presents the reliability statistics of the research questionnaire.

Table 13 Survey questionnaire reliability statistics (N=220)

Cronbach's Alpha	No. of Items
.852	8

Source: Primary data, (2024)

The results show a Cronbach's Alpha measure of 0.852. According to Johnston (2017) an alpha value of at least 0.7 shows high reliability of the instrument. Therefore, the value of 0.852 which was above 0.7 shows that the research questionnaire was reliable in collecting data, hence the results were more representative of the population as the questionnaire was internally consistent, such that it could repeatedly be used to collect data from the same population and similar results would be obtained.

4.7 Ethical compliance

Prior to commencing the study, ethical clearance was sought, because the involvement of human participants is needed and the use of data collected through the semi structured interviews and the questionnaire. DiCicco-Bloom (2006) highlighted that four ethical issues need to be considered. Firstly, the unpredictable damage of a risk needs to be avoided, secondly, the information of the participants has to be kept confidential and lastly, the participants have to be informed about the study. Before the semi structured interviews and the questionnaire survey were conducted, a participant information sheet was sent to the participants which explained that all the gathered data would be treated confidentially on both sides, the researcher and participants. Based on the

participant information sheet, a consent form was added that needed to be signed by the researcher and the participants.

4.8 Chapter Summary

The chapter focused on the analysis of the collected data. The analyzed data was then presented, interpreted and discussed. The chapter first of all gave the response rate of the study, of which the overall response rate was 92%. The chapter also presented the background and the demographic information of the respondents, mainly to determine their suitability in the research. The chapter then discussed the results in relation to the reviewed literature in the second chapter of this study. The following is the fifth and last chapter, which focused on the summary, conclusions and the recommendations of the study.

CHAPTER 5

SUMMARY CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This last chapter summarizes the research with its main findings, implications, limitations and recommendations for further work. In the next sub-chapter, a brief summary of the whole study on the *Model for Block chain Technology systems to improve Road Infrastructure Projects* is provided. This summary is separated into the different research objectives and the research aim of the dissertation. This is assembled by conclusions of the holistic research and how the objectives and aim were achieved. Finally, at the end of the summary, the research question will be answered. This is followed by the conclusion, the contribution of theory and practice, the limitations of the study and the recommendations for further work.

5.1 Summary of the research

This research in total is divided into five chapters. This first chapter provided an introduction to the research, and explained the research question, and the research aim and objectives. It also highlighted the background and problems of the construction industry, especially the road infrastructure industry. As an ending to the chapter, an overview of the whole research was provided, and the link between the different chapters was presented. In order to provide a comprehensive understanding of the current “state of knowledge”, in Chapter 2 a critical literature review, focusing on road infrastructure projects, the principles of Block Chain Technology and the information exchange, was presented. With the help of this literature review, a theoretical background for further research was laid and an understanding was established regarding the need for this research. In the literature review, the gap in the literature was also identified. During the literature review, the researcher learned from previous studies, experiences and studies. The chapter is an important chapter as well as it supported the development of the framework that is mandatory for the whole research.

The third chapter examined the philosophical perspectives, the research philosophies, research approaches and the methodological choices in order to gain an understanding of the same. These

are required for the research as they provide support in answering the research question and in achieving the aim with its objectives.

In Chapter 4, the chosen methods for the current research were presented. The motivation for the initiation in this research was explained and the chapter defined how the methods would be implemented. How the data after data collection were structured and analyzed was also presented. This step is essential for the development and validation of the research strategy.

In the same chapter, data collection from the semi-structured interviews and the questionnaire was presented.. In this chapter, information was collected for answering research objective 1 based on the data collected.

In the same chapter, the findings of three research objectives were analyzed with the help of the literature review chapter. As a result of this analysis, the research aim, “the development of the framework”, was implemented and generated. In this chapter, the framework is presented with its expected implications. Finally, the current chapter presents the summary of the main findings, implications, limitations and recommendations for further work and the original contribution to knowledge made through this research.

5.1.1 The research objectives and aim

The aim of this research is to develop a framework for the utilization of Block chain Technology to support the management of road infrastructure projects. In order to achieve this aim, several research objectives were created at the beginning of the research. A summary and an overview of these research objectives are given in Figure 7-3.

5.1.1.1 Research objective 1: To identify in which aspects of managing projects the principles of Block chain Technology can be effectively utilized

As is demonstrated in section 5.2.1, research objective 1 was achieved through conducting of the semi structured interviews, the administration of a questionnaire and the literature review. With the help of the literature review, it was possible to define the principles of Block chain Technology. Based on the literature review and the semi structured interviews, it became clear that, in the era of industry 4.0, development in the construction industry is essential. The transformation to digitization and new technologies in road infrastructure projects is limited, so an organizational support through pilot projects, frameworks and case studies is mandatory. One goal of the research is to deliver this support through a framework.

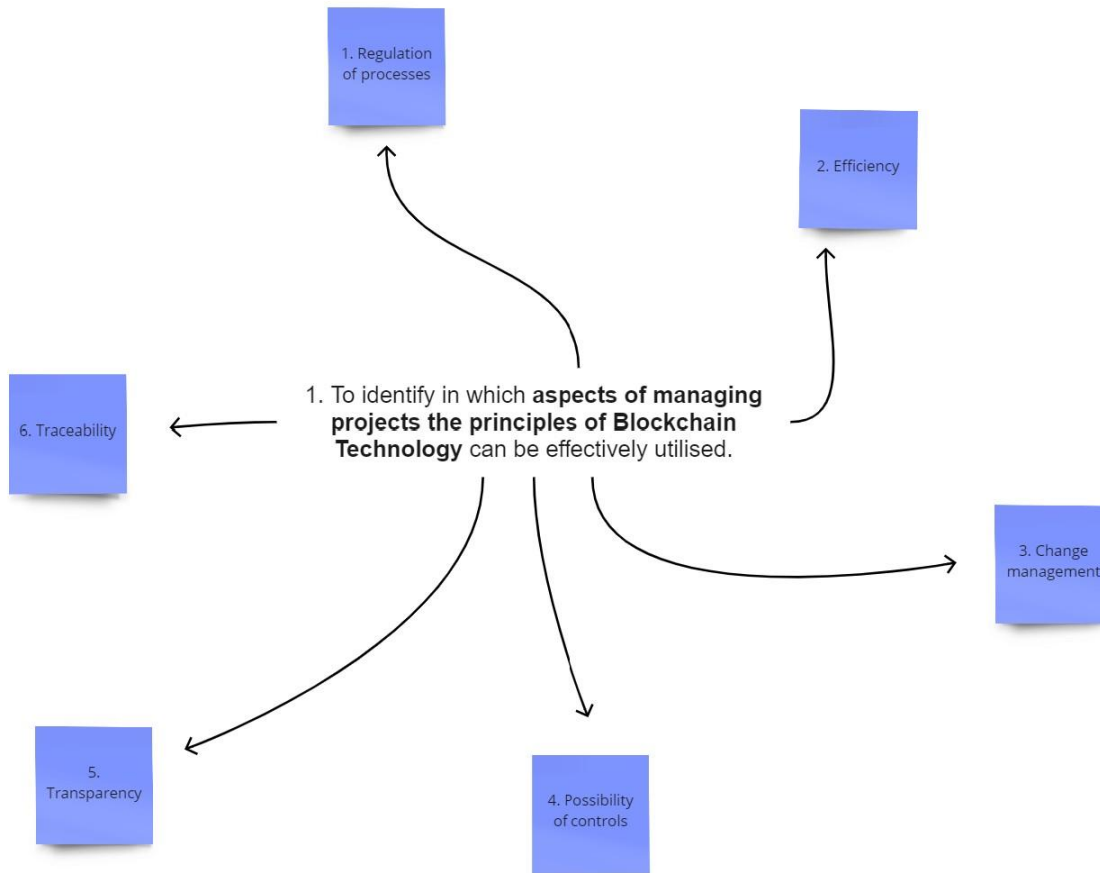


Figure 29 Research objective 1

The result of the first research objective showed that the principles of Block Chain Technology provide a lot of use in managing projects. The result of the semi structured interviews offered the suggestion that the principles of Block Chain Technology can support the processes, as is shown in Figure 30, in terms of regulation of processes, efficiency, change management, possibility of controls, transparency and traceability. These results facilitate a foundation for administering the questionnaire to gain a more detailed understanding of the research problem. Constitutive on these results, the basis for the whole research was laid.

5.1.1.2 Research objective 2. To explore the interrelation between the principles of Block chain Technology and the performance of managing road infrastructure projects.

Research Objective 2 was achieved through a qualitative method of semi-structured individual interviews and a questionnaire. Through the different interviews with different participants with

different backgrounds, themes and fields of the performance of road infrastructure project management were identified. The main results in terms of the performance of road infrastructure projects and their issues are listed below:

- Not sufficient information exchange between the different groups
- Every stakeholder is working in its silo
- Little transparency within the processes
- Afraid of transparency → Fear of control
- Reservation with new technologies

In order to overcome these issues, an investigation was made through the interviews to find if there is a relationship between them and the principles of Block chain Technology. The advantages and disadvantages are visualized in Figure 5.3. By comparing the challenges in road infrastructure projects and the advantages and disadvantages of Block chain Technology, the researcher was able to define the relationships between these two themes.

“To explore the interrelation between the Mechanism of the Principles of Blockchain

Technology and the Performance of Managing Road Infrastructure Projects”

To understand the interrelation between road infrastructure projects and the principles of Block chain Technology in the previous chapters the parameters transparency, different stakeholders, new technologies, traceability and immutability have been investigated in the different areas. As a first result it was found that the advantages the Block chain Technology is bringing can help in the challenges that are faced in road infrastructure projects.

The relationship between the principles of Block chain Technology and the road infrastructure projects can be confirmed with the statements of the interviewees and the sentiments written in the questionnaires by the respondents.

One of the interviewees confirmed that the biggest and most important advantages of Block chain Technology is in the field of trust, transparency and immutability.

5.1.1.3 Research objective 3: To appraise the barriers and the enablers to the utilization of Block chain Technology in the context of road infrastructure projects

Through the data collection and the analysis of the findings, the barriers to and the enablers of the utilization of Block chain Technology in the context to the road infrastructure projects were defined. The barriers in that context are the less experience that is available in the combination of the road infrastructure and the Block chain Technology and that it is questioned if this technology is necessary in that industry. The huge enabler that is given through that technology is that trust is a big problem in the road infrastructure field and, as the technology is known to be used when people do not trust each other, it would be a huge enabler in that field.

5.1.1.4 Research aim: To develop a framework for the utilization of Block chain Technology to support the management of road infrastructure projects

Bringing the outputs of the first three objectives together, the development of the research aim and the development of the holistic framework could be executed. The development of the holistic framework is based on a detailed literature review and is linked to the findings of the data collection that was conducted through semi structured interviews and questionnaires with experts from the road infrastructure sector and experts from the area of Block chain Technology. In the framework, the challenges of road infrastructure project management and the principles of Block chain Technology were presented and classified into two core themes each.

5.1.2 The research question

As a multi-method approach was chosen and the systematic application of this approach through a literature research, semi-structured individual interviews and the questionnaire is used, the research question: “*How can the Principles Block chain Technology be utilized for Managing Road Infrastructure Projects?*” can be answered as follows. Through the study, it was identified that the Principles of Block chain Technology together with an information exchange can be applied to the project management of road infrastructure projects. This result was achieved through the development of the framework with the classification into three themes with particular sub-themes. Hence, the research question is answered through the development of the holistic framework combining the challenges of the road infrastructure sector with the information exchange and the principles of the Block chain Technology as a solution. The developed

framework shows that the challenges that are faced in the project management of roads can be answered through a combination of the information exchange and the usage of the principles of Block chain Technology.

5.2 RECOMMENDATIONS FOR IMPLEMENTATION

The Department of Roads should create a clear roadmap outlining the phased implementation of block chain technology, starting with pilot projects and gradually expanding based on success.

A well-structured roadmap allows for manageable implementation while ensuring that each step in the process is thoroughly tested and optimized.

Begin with pilot projects in specific regions or for specific use cases (e.g., procurement, asset management, or maintenance tracking) before scaling to larger operations.

The DoR should form a dedicated block chain task force that includes representatives from all relevant stakeholders (e.g., contractors, local governments, regulatory bodies, and technology experts)

Early engagement with stakeholders will help to align block chain adoption with the needs of different parties and ensure that the technology can address their concerns, such as data security, access control, and transparency.

Host workshops and collaborative meetings to educate stakeholders about block chain's potential benefits and to ensure their buy-in. This will also help clarify any concerns about the transition to a block chain-based system. The DoR should invest in training programs to upskill its staff on block chain technology and its applications within the road infrastructure sector.

Successful block chain implementation requires staff who understand both the technology itself and how it can be applied to road projects. Provide specialized courses and certifications in block chain for DoR personnel, with a focus on smart contracts, decentralized ledger technology, and block chain security practices.

5.2.1 Contribution to knowledge

The contribution to knowledge in this study on “*Model for Block chain Technology systems to improve Road Infrastructure*” is separated into the contribution of theory and the contribution of practice, which will be presented in the next two sub-chapters.

5.2.2 Contribution to theory

Prior to the literature review, it was addressed that, for effective information exchange (Milne, 2015), transparency is required (Jacob and Varghese, 2018). To deliver that transparency in an information exchange, it was highlighted that trust is the foundation. As intensive research in the field of Block chain Technology was conducted in Chapter 2, it was found out that Block chain Technology is built on a distributed ledger and through this decentralization, transparency, traceability and immutability are facilitated. Because these parameters can be guaranteed through the decentralization, the trust level is very high and consequently the transparent processes. To implement the principles of Block chain Technology into an information exchange system, trust would need to be resilient.

Specifically, the current research provides new insights into the definition and characteristics of information exchange in the field of the principles of Block chain Technology. The theory is also highlighting the critical connection in terms of the topic of trust within road infrastructure project management and between road infrastructure projects and new technologies.

The outcomes of the findings of the research provide a new contribution to theory in the balance of the information exchange and the principles of Block chain Technology.

Throughout the findings and the discussion of the research, the obligation of a transparent and traceable process is introduced. In particular, it is presented that trust is increasing in the case of a transparent and traceable process. It is also highlighted that these two areas of “trust” and “transparency and traceability” are dependent on each other.

Expanding upon this, within the research it was possible to reach a first consensus that presumed that the design of the framework between road infrastructure project management, information exchange and the Principles of Block chain Technology needs to meet a balance in terms of a transparent information exchange between the different stakeholders involved in road infrastructure project management.

The most notable effect on an imbalanced information exchange falls under the representation of the limits of information sharing between the stakeholders. This leads to a lack of information and, because of the fear of control and transparency.

5.2.3 Contribution to practice

Because of the strong involvement of the participants through the data collection, the researcher is able to make a contribution to practice at the end of the research. From the view of the practical perspective of the contribution to knowledge, the research has contributed to the support for using new technologies, especially the principles of Block chain Technology, in complex road infrastructure projects. With the help of the framework, this work has contributed to make the information exchange in the field of road infrastructure projects more transparent and thus to support processes related to traceability and immutability. This framework is an advanced method, if properly applied, to support road infrastructure projects in terms of transparency in internal and external processes. The interaction of the parameters of the information exchange (the information sharing) and the parameters of the Block chain Technology that are related to the distributed ledger are supporting in handling the challenges of road infrastructure project management. If the tool for the information exchange would be set up based on the principles of the Block chain Technology, the road infrastructure project management could be optimized in terms of transparency and traceability that would lead to more trust. Furthermore, it is expected that this framework will be used by project managers, clients and in supply chains, especially in long-term projects. Another important aspect of the framework is to use it in discussions and basically in information exchange topics to provide stakeholders with a better awareness and understanding of processes in a project. Ultimately, the framework provides an exceptional opportunity to apply the skills of the principles of Block chain Technology to a project and thus improve processes.

Contribution to practice will also help to improve processes in terms of information exchange in the field of road infrastructure project management and, if properly applied, the framework can increase the use of new technologies in terms of the principles of Block chain Technology in the field of road infrastructure project management. In order that the framework can be properly applied, the users need to understand how to manage the project and do need a holistic overview of the whole project. The core application of this holistic framework within road infrastructure project management is expected through the whole process of the project management. The

framework is made for the use of clients, contractors, sub-contractors, project management, planners and builder.

Through the utilization of the framework it is also expected that organizations, architects and engineers will benefit. The main applicability of this framework is expected through project managers having an overview of the whole project. The result of the current research is that, with the use of the framework, the different stakeholders involved in a project are able to understand the internal and external processes with the help of transparency between all the different groups. The given transparency in the framework offers traceability and immutability and that leads to the fact that groups and participants do trust each other. An important task of the framework is that all parameters of all three core themes are simplified and all kinds of users are able to understand the idea and the meaning of the framework.

5.3 Limitations

As is known, all research projects are accompanied by limitations. The relevant limitations for the current research that need to be considered are the following:

- The research was only focused on the road infrastructure sector; it was not conducted in other projects. Thus, the research cannot be generalized to other industries.
- As the Block chain Technology itself is normally known in context with the currency Bitcoin, the researcher needed to be really careful in the research that the participants were not afraid and biased from the very beginning. The feeling arose that the Block chain Technology itself could be a too big technology and too complicated.

The generated framework has not been tested in a real project. With a case study in a project, or the implementation in a long-term project, further results and a further improvement of the framework are expected. Although the themes of the framework are simplified, the framework auditors do need to understand the framework and it is necessary to understand the challenges of the road infrastructure and to understand the principles of the Block chain Technology.

However, when applying this framework, it needs to be considered that the project manager using this framework needs to understand the idea of the framework very well to achieve the results. A

reasonable approach to overcome this could be in-depth trainings of the use of the framework. Since the framework seeks to establish trust the framework should not be used to blame stakeholders or to make accusations of guilt.

5.4 Recommendation for further study

As was mentioned in the introduction chapter, there is a huge margin in terms of the productivity in the different industries compared to the construction industry. In order that the productivity in the field of road infrastructure can also grow, there need for a deeper investigation of new technologies and digitization in this field.

The findings of the current research provide a respectable foundation to conduct deeper investigations in the field of Block chain Technology. Further research also needs to consider investigating the implementation of the framework in a project environment with different durations to explicitly identify the limits of the suitability of this framework within projects. It also needs to be thought about that participants need to be trained on how the principles can be adopted into the project environment. For this adoption, a training programme should be developed.

5.5 Chapter summary

In the last chapter of the research on “A model for Block Chain Technology system to improve road infrastructure”, the efforts of the researcher are summarized, with the research findings, its implications and its limitations. In this research, the research question has been met and the research aim has been conducted. The framework developed in this research was developed through semi-structured interviews, questionnaires and a very detailed literature review.

Furthermore, the research has invigorated the knowledge and the existing experience about challenges in road infrastructure projects and principles of Block chain Technology. Moreover, a correlation between the road infrastructure, the information exchange and the principles of Block chain Technology has been recognized.

This last chapter in the study also supports the understanding of how this research and the holistic framework present a contribution to knowledge in the areas of theory in practice. With the help of the limitations of this work, it is demonstrated how this field can be developed to gain acceptance. Closing the research, the way in which this research and the developed framework could promote the principles of Block chain Technology in the field of road infrastructure projects was well defined.

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APPENDICES

Appendix 3: Interview Guide for Department of Roads Engineers and Senior Managers

BINDURA UNIVERSITY OF SCIENCE EDUCATION FACULTY OF COMMERCE



October 2024

Dear Respondent

My name is Adam Howard Gwete, a final year student at Bindura University of Science Education at the Graduate School of Business, student number B232071B and doing a postgraduate degree, Master in Leadership and Corporate Governance. As part of my degree program, I am required to do a research project, and therefore request for your assistance to this end. My research project is titled “*A model for Block Chain Technology system to improve road infrastructure: A case of the Department of Roads*”. I therefore kindly ask you to respond to the questions provided and the responses will be solely used by myself to complete this research. The questionnaire is made up of mostly open-ended questions, therefore feel free to express yourself in your own words. Your corporation in participating in this interview will be greatly appreciated and all the information you give will be treated in the strictest confidence.

Thank you in advance.

Contacts

Phone: +263 775 730 082; **Email:** adamhgwete@gmail.com

Section A: Background Information of Respondents

Semi-Structured Interview Guide

Introduction

"Thank you for participating in this interview. The purpose of this research is to explore how block chain technology can be integrated into the road infrastructure sector to improve transparency, efficiency, and management. Your insights will help develop a model for the Department of Roads. This interview will take around 30-45 minutes, and your responses will remain confidential. Feel free to share openly, and let me know if you need clarification at any point."

Background Information

1. Gender.

Male [☐] Female [☐]

2. What is your age range?

18-30 years [☐] 31-45 years [☐] 45-60 years [☐] 60+ years [☐]

3. What is your marital status?

Married [☐] Widow/er [☐] Divorced/Separated [☐] Single [☐]

4. What is your level of experience at CBZ?

0-5 years [☐] 6-10 years [☐] 11-15 years [☐]
16-20 years [☐] 21-25 years [☐] 26-30 years [☐]
30+ years [☐]

1. Could you please tell me a little about your role and your experience with the Department of Roads?

2. How long have you been involved in managing or engineering road infrastructure projects?

3. How familiar are you with block chain technology?

4. Have you had any experience or exposure to block chain in your current role or previous roles?

Section B: Examining in which aspects of managing road infrastructure projects can the principles of Block chain Technology be effectively utilized in the Department of Roads.

1. Road infrastructure projects often involve numerous stakeholders. How do you think Block chain's transparency principle could be applied to improve visibility across all phases of the project (planning, execution, monitoring, etc.)?

.....
.....

2. What challenges do you foresee in implementing Block chain for managing road infrastructure projects? How can these challenges be addressed?

.....
.....

3. Are there any specific legal, technological, or organizational barriers that may prevent the effective use of Block chain in these projects?

.....
.....

4. Do you think it would be beneficial to run a pilot project using Block chain in road infrastructure management? If so, which specific aspects of the project would be best suited for a pilot?

.....
.....

5. What kind of policies or regulatory frameworks would be required to enable the adoption of Block chain in road infrastructure management?

.....
.....

Section C: Extent of belief that there are interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects

1. What do you understand by the core principles of Block chain Technology, such as decentralization, immutability, and transparency? Can you explain these principles in simple terms?

.....
.....

2. Do you think Block chain could be a good fit for road infrastructure projects, given its principles? Why or why not?

.....
.....

3. How important is transparency and accountability in managing road infrastructure projects? In what ways do you think Block chain's transparency principle could improve these factors?

.....
.....

4. Road infrastructure projects often involve multiple stakeholders (government agencies, contractors, suppliers, etc.). Do you think Block chain's decentralized nature could help improve communication and coordination among them?

.....
.....

Section D: Assessing the barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads.

1. What do you perceive as the biggest technological challenges in implementing Block chain for road infrastructure projects?.....

2. What do you think are the financial barriers to adopting Block chain Technology for road infrastructure projects?.....

3. Do you think the current staff and stakeholders have the necessary skills to work with Block chain technology? If not, what kind of training or expertise would be required?

.....
.....

4. Do you think there are any legal or regulatory challenges that might hinder the adoption of Block chain in infrastructure management?

.....
.....

5. How do you think Block chain could improve transparency and accountability in road infrastructure projects?

.....
.....

6. Can you provide examples of how real-time tracking through Block chain might benefit the project stakeholders?

.....
.....

7. In your opinion, how would Block chain technology improve efficiency in managing road infrastructure projects?

.....
.....

8. Do you think Block chain can streamline contract management, procurement, or progress monitoring? How?

.....
.....

Section E: Development of a Framework for the Utilization of Block chain Technology in Road Infrastructure Projects.

1. What is your level of familiarity with Block chain technology, and how do you perceive its relevance to road infrastructure management? Justify

.....
.....

How do you think Block chain technology could improve the management of road infrastructure projects? Justify

.....
.....

3. In your opinion, what are the essential components that should be included in a framework for implementing Blockchain in road infrastructure projects? [Tick preferred]

- Regulatory and legal frameworks
- Technological requirements (e.g., platform selection, integration with existing systems)

- Stakeholder collaboration and roles
- Training and capacity building

4. How do you envision the integration of Blockchain with existing project management systems (e.g., contract management, financial tracking, and scheduling tools)? Comment

.....

5. What do you think would be the most effective strategy for phased implementation of Blockchain technology in road infrastructure projects?

.....

Wrap-Up

"Thank you for your insights today. Your contributions will play a key role in helping shape a model for block chain technology in road infrastructure. Is there anything else you would like to share or any additional thoughts you have on the topic?"

THE END: THANK YOU FOR PARTICIPATING

Appendix 4: Questionnaire for Employees in the Department of Roads

**BINDURA UNIVERSITY OF SCIENCE EDUCATION
 FACULTY OF COMMERCE**



October 2024

Dear Respondent

My name is Adam Howard Gwete, a final year student at Bindura University of Science Education at the Graduate School of Business, student number B232071B and doing a postgraduate degree, Master in Leadership and Corporate Governance. As part of my degree program, I am required to do a research project, and therefore request for your assistance to this end. My research project is titled “*A model for Block Chain Technology system to improve road infrastructure: A case of the Department of Roads*”. I therefore kindly ask you to respond to the questions provided and the responses will be solely used by myself to complete this research. The questionnaire is made up of mostly open-ended questions, therefore feel free to express yourself in your own words. Your corporation in participating in this interview will be greatly appreciated and all the information you give will be treated in the strictest confidence.

Thank you in advance.

Contacts

Phone: +263 775 730 082 ; **Email:** adamhgwete@gmail.com

Section A: Background Information of respondents

Interviewer to tick in the correct box

Questionnaire: A Model for Block chain Technology to Improve Road Infrastructure

Introduction

Thank you for participating in this questionnaire. The purpose of this research is to gather insights into how block chain technology can improve road infrastructure management. Your responses

will remain confidential and will be used to develop a model for integrating block chain technology into the Department of Roads. The questionnaire will take approximately 15-20 minutes to complete.

Section 1: General Information

Tick [✓] inside the box corresponding to one most applicable answer for each question in this section

1. What is your gender?

Male [] Female []

2. What is your age range?

18-30 years [] 31-45 years [] 45-60 years [] 60+ years []

3. What is your marital status?

Married [] Widow/er [] Divorced/Separated [] Single []

4. What is your level of experience at the Department of Roads?

0-5 years [] 6-10 years [] 11-15 years []
16-20 years [] 21-25 years [] 26-30 years []
30+ years []

5. What is your role in the Department of Roads?

Senior Manager []

Engineer []

Other (Please specify): _____

6. How long have you been working in the road infrastructure sector?

Less than 1 year []

1–5 years []

6–10 years []

More than 10 years []

7. Have you previously worked on any projects involving block chain technology?

Yes []

No []

Section 2: Examining in which aspects of managing road infrastructure projects can the principles of Block chain Technology be effectively utilized in the Department of Roads.

1. How beneficial is Block chain's transparency principle for improving accountability in procurement, contracts, and progress reporting? (Scale: 1 = Not beneficial, 5 = Very beneficial)

2. Which phase(s) of road infrastructure projects do you think Block chain would be most beneficial in? (Multiple choice: Planning, Procurement, Execution, Monitoring, Risk Management, Other)

3. Do you think Block chain can reduce the risk of delays or cost overruns in road infrastructure projects? (Yes/No) If yes, explain how.

4. In your opinion, what are the key aspects of road infrastructure projects that Block chain could address most effectively? (Open-ended)

5. What are the major challenges in applying Block chain to road infrastructure management? (Open-ended)

Section3: Extent of belief that there are interrelations between the principles of Block chain Technology and the performance of Managing Road Infrastructure Projects

1. In your opinion, how effective could Block chain's decentralization principle be in improving communication among stakeholders in road infrastructure projects? (Scale: 1 = Not effective, 5 = Very effective) []

2. How likely is Block chain's immutability principle to help resolve disputes or prevent fraud in road infrastructure projects? (Scale: 1 = Not likely, 5 = Very likely) []

3. How beneficial do you think smart contracts could be in managing milestones, payments, and project timelines for road infrastructure projects? (Scale: 1 = Not beneficial, 5 = Very beneficial) []
4. How important is data security in road infrastructure projects? How well do you think Block chain's security features can address these concerns? (Scale: 1 = Not important, 5 = Very important) []
5. To what extent do you think Block chain's principles (transparency, decentralization, immutability, and smart contracts) are interrelated with the overall success and performance of road infrastructure projects? (Scale: 1 = Not interrelated, 5 = Strongly interrelated) []

Section 4: Assessing the barriers and the enablers to the utilization of Block chain Technology in the context of Road Infrastructure Projects in the Department of Roads.

1. How do you perceive the technological challenges of adopting Block chain in road infrastructure projects? (Scale: 1 = Not a barrier, 5 = Major barrier)
2. How significant is the financial investment required to implement Block chain? (Scale: 1 = Not significant, 5 = Very significant)
3. How beneficial do you think Block chain would be for improving transparency in road infrastructure projects? (Scale: 1 = Not beneficial, 5 = Very beneficial)
4. How likely is Block chain to help in reducing costs and financial mismanagement? (Scale: 1 = Not likely, 5 = Very likely)

Section 5: Development of a Framework for the Utilization of Block chain Technology in Road Infrastructure Projects

1. How familiar are you with Block chain technology in the context of road infrastructure projects?
Very familiar
Somewhat familiar

Not familiar at all

2. Do you believe Block chain technology could improve the management of road infrastructure projects?

Yes, significantly

Yes, moderately

No, not really

No, not at all

3. In your opinion, what areas of road infrastructure management would benefit the most from Block chain technology? (Select all that apply)

Procurement and contract management

Project tracking and reporting

Transparency and accountability

Budget and financial management

Risk management

Stakeholder collaboration

Others (please specify)

4. What key components should be included in a framework for the adoption of Blockchain technology in road infrastructure projects? (Select all that apply)

Clear regulatory and legal guidelines

Standardized procedures for data sharing and reporting

Block chain platform selection (e.g., public vs private Block chain)

Integration with existing project management tools (e.g., financial systems, procurement platforms)

Stakeholder engagement and collaboration strategies

Data security and privacy protocols

Training and capacity building for staff and stakeholders

Pilot testing and evaluation phases

Others (please specify).....

5. How important is it to have a phased implementation plan for Blockchain in road infrastructure projects?

Very important

Important

Moderately important

Not important

6. What technological infrastructure would be necessary to support the implementation of Blockchain in road infrastructure projects?

Cloud-based systems for data storage and access

Blockchain platform (e.g., Ethereum, Hyperledger, etc.)

Internet of Things (IoT) devices for real-time data collection

Integration with existing systems (e.g., procurement, financial systems)

High-level data encryption and cybersecurity protocols

Others (please specify)

Conclusion

Thank you for your time and valuable insights. Your responses will greatly contribute to developing a model for integrating block chain technology in road infrastructure management.

THE END: THANK YOU FOR PARTICIPATING

Appendix 3: Research request letter



ROADS

DEPARTMENT OF ROADS
Ministry of Transport & Infrastructural Development

CMU BUILDING, KHAMI RD
P.O. BOX 3146, BULAWAYO

Tel: 09 61284/6, 61301

Fax: 09 63108

E-mail: kamutema@transcom.gov.zw

ZIMBABWE

10 October 2024

RDS/10/24

Attention: Gwete Adam Howard

RE: REQUEST FOR APPROVAL TO CONDUCT RESEARCH STUDY

We write to advise that your request to conduct a research study within our organisation has been successful.

We wish you all the best in your study.

Yours sincerely,

KANGARA J.S

DIRECTOR ROADS