Adoption of the Big Data concept in the Construction Industry

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PhD Thesis 2023

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A thesis submitted in partial fulfilment of the requirements of the University of Wolverhampton for the degree of Doctor of Philosophy (PhD)

May 2023

Signature: 

Date: May 30th, 2023

ABSTRACT

The Big Data (BD) boom has increased exponentially in recent years, reaching even the most traditional industries. In construction, the migration towards sustainability and new technologies that produce user and environmentally friendly projects is now a requirement in almost every country. Meanwhile, BD technology has become a possible solution to the challenges that the industry faces nowadays with some authors naming this technology as the future of construction. However, despite this reception, studies that explain in detail the factors that favour the adoption of BD are scarce or non-existent and the adoption itself has proven to be a challenge, especially in industries such as construction that are not technology driven. Understanding the critical factors that influence BD adoption has become the focus of many industries that seek to exploit the benefits offered by this technology. Therefore, the aim of this research is to explore the adoption of BD in the construction industry. First, the awareness of the Dominican Republic's construction industry on the BD concept, its characteristics, and benefits was assessed. The key drivers, strategies, and challenges regarding the adoption of BD in the industry were also investigated. A qualitative method was selected to identify these strategies due to the lack of maturity and the scarcity of sources that address the subject. Semi-structured interviews were selected as the data collection tool, and content and thematic analysis were chosen to acquire an in-depth knowledge of the interviews. Endsley's model of situational awareness was adapted to provide a better understanding of the industry's awareness of BD. The sampling technique adopted was non-probabilistic due to some of the specific criteria identified during the secondary data collection process. In the data collection process, 21 interviews were conducted with representatives of 19 organisations with an undoubted presence in the construction market of the Dominican Republic. The results showed that there is an overall basic level of awareness about BD in the construction industry of the Dominican Republic. Moreover, nine key drivers for BD adoption were identified and grouped into internal and external drivers. Additionally, four main strategies or central policies for adopting the technology and seven main challenges were identified. These findings were used to develop an organisation readiness assessment tool and a strategic framework for BD adoption in the construction industry. This study concluded that new technologies such as Big Data (BD) require a change in the industry's culture and the adoption of digital approaches to be fully implemented. The findings of this research provide valuable insights that can help the construction industry adopt BD technology, thus accessing the short and long-term benefits that this technology offers.

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Throughout the journey of this research, I have received an incredible amount of support and assistance. I would first like to thank the Government of the Dominican Republic for sponsoring this research; without their support, this research would still only be a dream.

I would like to express my deepest gratitude to my Director of Studies, Dr Subashini Suresh, and my Supervisor, Dr Suresh Renukappa. Your guidance, support and understanding made this research a reality.

This endeavour would not have been possible without the support of my friends and PhD colleagues. Thank you for sharing your knowledge and experiences with me, for accompanying me, and for making this journey bearable.

Lastly, but by no means least, all my gratitude goes to my family and specially my husband Victor, who continually provided their support in every way imaginable. I feel very blessed to have you all in my corner.

DEDICATION

This study is wholeheartedly dedicated to the loving memory of my mother, Maria Soledad Veras Duran, who watches over me from heaven.

RESEARCH OUTPUTS

SCIENTIFIC JOURNAL PAPER PUBLICATIONS

- Reyes Veras, P., Renukappa, S. and Suresh, S. (2022), *"Awareness of Big Data concept in the Dominican Republic construction industry: an empirical study*", Construction Innovation, Vol. 22 No. 3, pp. 465-486. https://doi.org/10.1108/CI-05-2021-0090
- Reyes Veras, P., Renukappa, S. and Suresh, S. (2021). *Challenges faced by the adoption of big data in the Dominican Republic construction industry: an empirical study.* Journal of Information Technology in Construction (ITcon), Special issue: 'Construction 4.0: Established and Emerging Digital Technologies within the Construction Industry (ConVR 2020)', Vol. 26, pg. 812-831, DOI: 10.36680/j.itcon.2021.044
- Key Drivers for Big Data Adoption in the Dominican Republic Construction Industry: An Empirical Study. (*Accepted for publication in the Engineering Sustainability Journal, Proceedings of the ICE).*

CONFERENCE PAPER PUBLICATIONS

- The Adoption of Big Data Concepts for Sustainable Practices Implementation in the Construction Industry, 2018 IEEE/ACM International Conference on Utility and Cloud Computing Companion (UCC Companion), December 2018, Date Added to IEEE Xplore: 10 January 2019. DOI: 10.1109/UCC-Companion.2018.00079
- Awareness of big data concept in the Dominican Republic construction industry: an empirical study, Enabling the Development and Implementation of Digital Twins: Proceedings of the 20th International Conference on Construction Applications of Virtual Reality, October 2020, Middlesbrough, United Kingdom, Teesside University Press. ISBN: 978-0-9927161-2-7.
- Strategies for implementing big data concept in the construction industry of the Dominican Republic. Industry 4.0 Applications for Full Lifecycle Integration of Buildings Proceedings of the 21st International Conference on Construction Applications of Virtual Reality, January 2022, Teesside University Press. ISBN: 978-0-9927161-3-4

CHAPTER 1. INTRODUCTION

This section is the introductory chapter of this study. It discusses the background and research justification. Furthermore, the chapter explores the research aim, objectives, and research questions. Additionally, it presents the methodology adopted by this study, reviews the contributions to the existing subject knowledge, and discusses the scope and limitations. Finally, the chapter showcases the structure followed within this thesis.

1.1 Research Background

The construction industry plays a significant role in economic growth around the world (Alaloul et al., 2021; Opoku et al., 2021). It is one of the main characters in resource consumption, thus has an ever-demanding need for technology developments (Willar et al., 2021). Construction methods and materials have evolved little or not at all in the last few decades, contrary to the needs of society and the environment, both of which require that projects provide experiences that are more tailored to the users' needs while adequately managing resources in all stages of development (Cross, 2018).

This resistance to change has been challenged in recent years. Trends like industry 4.0 and technologies such as building information modelling (BIM), the internet of things (IoT), and smart devices are making waves in the industry and pushing for further digitalisation (Newman et al., 2020; Oladokun et al., 2021). These technologies are also closely related to Big Data (BD) in construction as they are essential in providing the infrastructure for data creation, transmission, and storage (Han et al., 2022).

At the same time, the industry faces a series of shortcomings which prevents the efficient delivery of products and services, costing the world economy about $1.6 trillion annually (Yousif et al., 2021). Challenges such as stagnated productivity levels, health and safety, an ageing workforce, skill shortages, and poor technology adoption are among the leading causes of the industry's decline (Leeds, 2020; Jones, 2018; Ocean, 2021; Opoku et al., 2021).

In recent years, organisations have been able to access more data than ever. But unless they know how to analyse BD, this will not translate into value (Oracle, 2020).

Big Data can be considered any big amount of information that is contained digitally. In order to better understand BD, it is necessary to recognise the difference between data and information. These terms “data” and “information” are frequently interchanged. They are, however, very different. According to Meleen (2021), data can be defined as compilation of distinctive facts or statistics. Data is a raw form of knowledge and, on its own, doesn’t carry any significance or purpose. Data can come in the form of text, observations, figures, images, numbers, graphs, or symbols. For example, data might include individual prices, weights, addresses, ages, names, temperatures, dates, or distances. Meanwhile, information is defined as knowledge gained through study, communication, research, or instruction. Essentially, information is the result of analysing and interpreting pieces of data. The figure below lists the main differences between data and information.

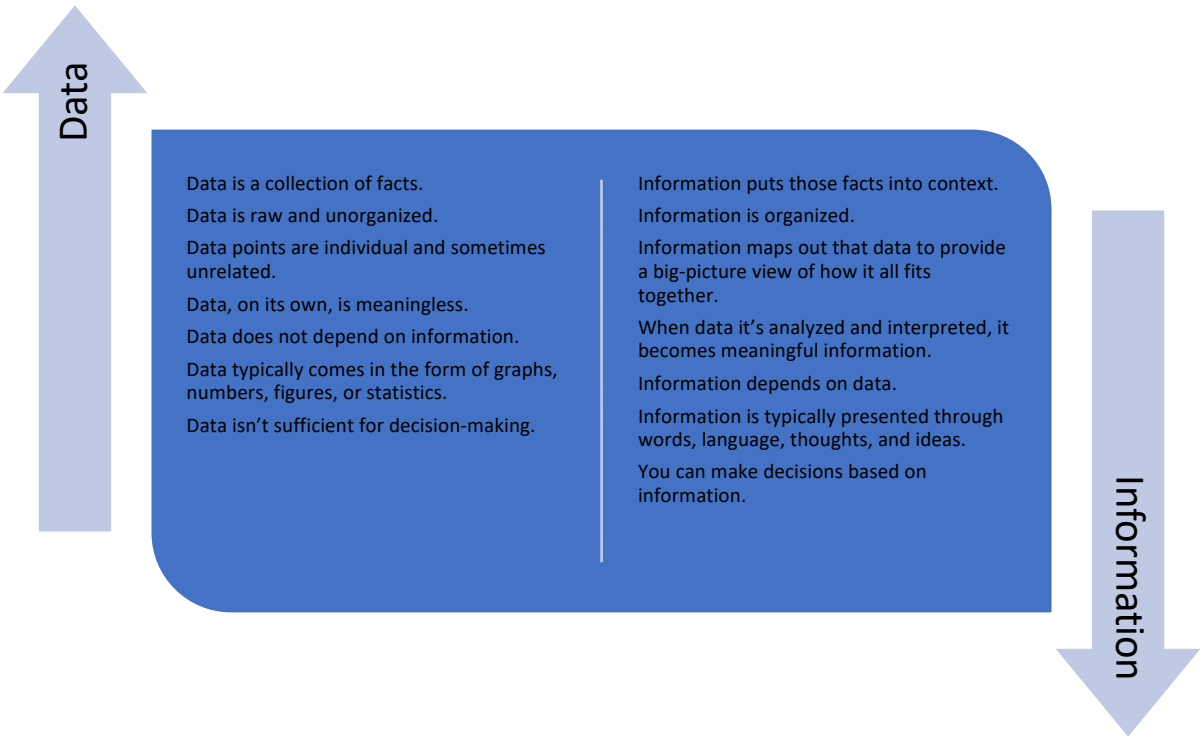


Figure 1.1: DIFFERENCES BETWEEN DATA AND INFORMATION

Source: Adapted from Meleen (2021).

Ultimately, when referring to BD technology, we speak of the cumulus of information that escapes the capacity of traditional processing tools (Miloslavskaya & Tolstoy, 2016). In other words, the dataset is too big or too complex for conventional data analysis processes and has specific characteristics such as volume, variety, velocity,

and value (Tabesh et al., 2019). Big Data analysis is focused on extracting valuable insights from this big cumulus of information to allow organisations to improve their decision-making process, deliver better services and customer experiences, enter new markets, and increase revenue (Bange et al., 2015).

This technology is still relatively young in digitally driven industries such as healthcare, retail, and telecommunications (Chen et al., 2020; Tabesh et al., 2019). Global BD adoption is growing exponentially with each passing day. By 2021, the BD market was expected to reach around $99 billion dollars (Kulkarni, 2019). However, successful adoption is tightly attached to digitally driven industries (Chen et al., 2020; Rabhi, Falih et al., 2019; Tabesh et al., 2019).

Still, the construction industry is struggling to widely adopt the technology and is being held back by slow innovation adoption. Despite the great reception that BD has had in other sectors and how every day more digital developments are pushing the construction industry to evolve at a much greater pace than ever, construction is still among the least digitalised industries today (Opoku et al., 2021; Abioye et al., 2021).

The industry's inability to embrace technological advancement contradicts the amount of digital data and the dependency that is growing in the construction sector at great speed driven by the adoption of digital trends, software, and tools as well as the migration from paper-based project development (Chen et al., 2020; Caesarius & Hohenthal, 2018; Opoku et al., 2021).

The overall benefits of BD implementation offer straightforward solutions to the challenges faced by the industry (Wong, 2020; Morrison, 2021).. This phenomenon is supported by the rise in BD adoption by construction companies worldwide (Hwang et al., 2022). Nowadays, BD can be applied in every stage of the project lifecycle, providing improved decision-making and benefiting all stakeholders (Stannard, 2021). The industry-wide adoption of BD in construction would mean a potential solution to unnecessary waste creation, the inefficient use of equipment and materials, and inefficient project analysis of the risks and costs. At the same time, the adoption would produce improved management efficiency, improved budget estimations, lower project risks, increased building efficiency, reduced environmental impacts, improved working conditions, and enhanced sustainability (Wong, 2020; Morrison, 2021).

Notwithstanding this, there is no clear path to successful BD adoption. Technology integration generally depends on the industry's ability to handle and integrate new technologies (Silverio-Fernandez et al., 2019). Still, because of its application in resource management, the project life cycle and decision-making, BD has been identified as a future critical technology for the construction industry, enabling it to keep up to date with the demands of today's society (Vellante, 2021).

At the same time, the construction industry of the Dominican Republic is a living example of an industry that has started the journey towards digitalisation. There are already documented efforts of BIM, smart devices, and Drone technology implementations that can be considered a pillar for BD-related data generation. In the near future, this industry will face the same drivers, challenges, and potential benefits of BD adoption. This situation means that the construction industry of the Dominican Republic is in an advantageous position for the study of the implementation and development of new technologies such as BD since there is a demonstrated willingness on the part of the organisations.

1.2 Research Justification

Nowadays, our dependence on the internet has grown exponentially as well as the amount of data generated by every digital interaction we make. Big Data analysis provides valuable insights so then businesses can improve their processes, increase efficiency, and gain a competitive advantage (Chatterjee et al., 2022). Because of this, businesses need to embrace the paradigm shift that BD represents (Experian, 2020). Additionally, organisations across all industries are looking to adopt the technology to increase their revenue and improve their customer services, marketing strategies and lower production costs.

The construction industry plays a significant role in the evolution of society by supporting the development of the built environment. It has also become one of the main characters in resource consumption, waste creation, and CO2 emissions produced (Willar et al., 2021). So far, the focus of the industry has been economic growth. Still, as society shifts towards more sustainable development, the construction industry is being pushed by trends like industry 4.0 to adapt and satisfy the demands of society, prioritising social and environmental action (Newman et al., 2020; Oladokun et al., 2021).

These new requirements, which affect both existing and new projects, are forcing the industry to modernise and adopt technologies that allow for the more conscientious management of resources while also improving efficiency in the project delivery processes (Cross, 2018).

The construction industry possesses a series of characteristics that makes it unique. Some features can be considered universal such as its enormous labour force, complexity and having the government as a main client while some other rank in importance depending on the country (Faizal, 2010). For instance, in its study "Characteristics of the Construction Industry from the Marketing Viewpoint: Challenges and Solutions" Mokhtariani et al. (2017) compiled the main characteristics of the construction industry. The study identified elements such as high complexity, high risk, clients with power for bargaining, and inability to induce demand. Later on, during the literature review, they presented the elements listed in the figure below as the main characteristics of the construction industry.

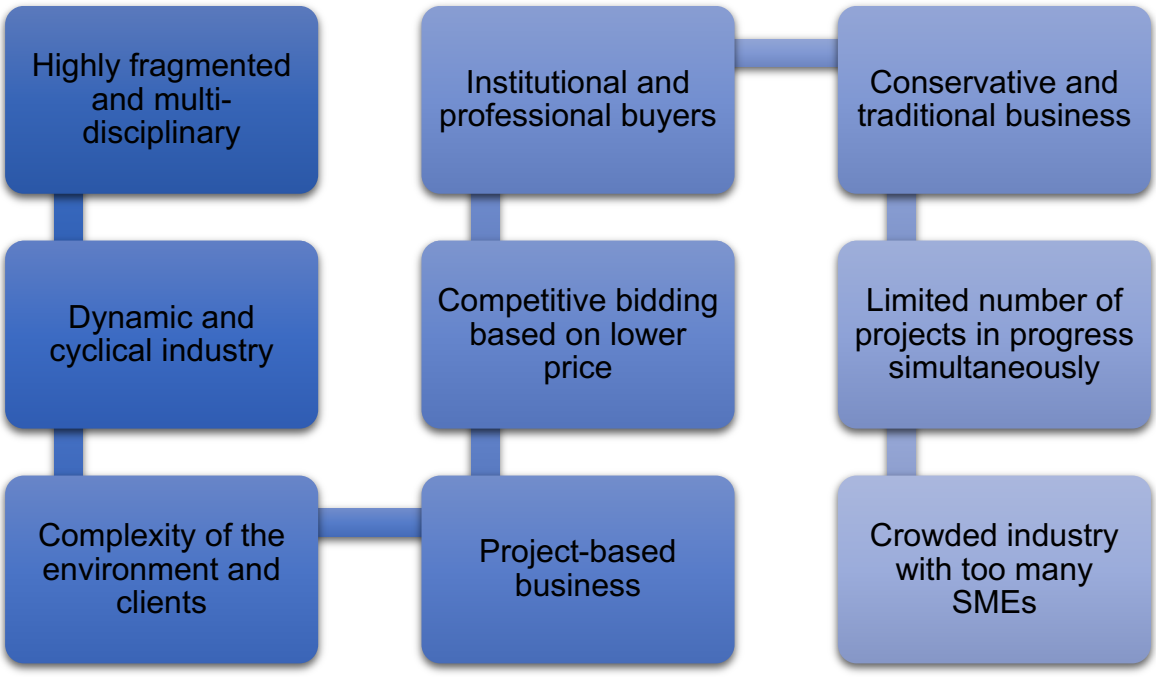


Figure 1.2: Characteristics of the Construction Industry

Source: Adapted from Mokhtariani et al. (2017)

At the same time, Boadu et al. (2020), studied the case of developing countries where some of the characteristics presented above can still be identified such as fragmentation and the large number of SMEs or small contractors, and some others

come to light such as the huge number of informal sector participation and the reliance on temporary labour force.

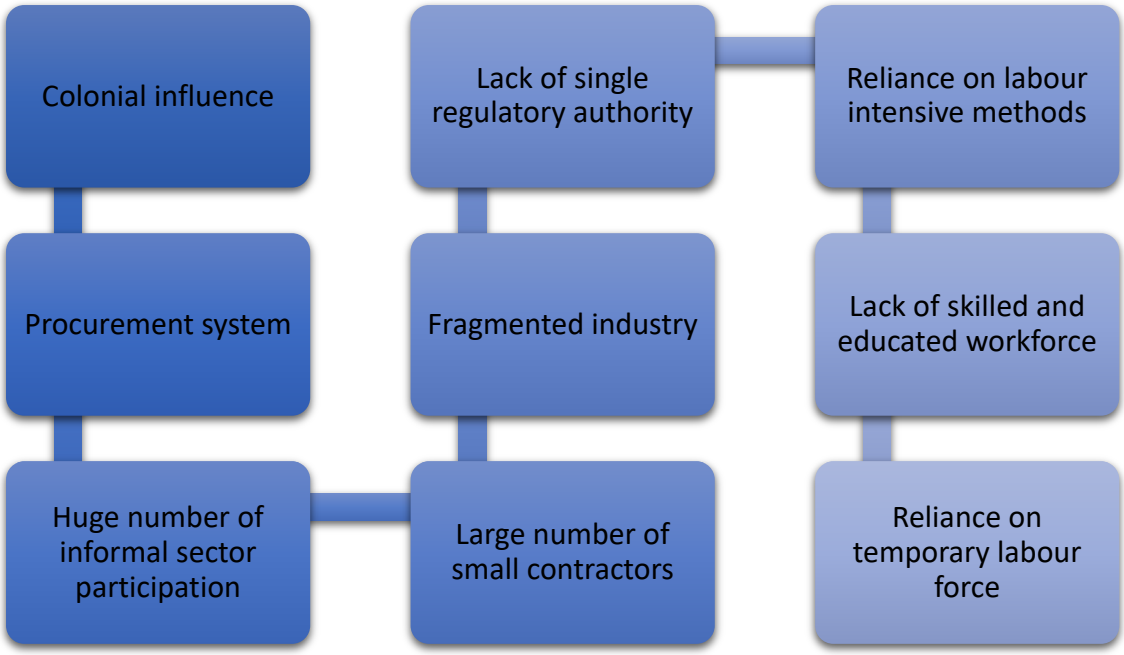


Figure 1.3: Characteristics of the Construction Industry in Developing Countries

Source: Adapted from Boadu et al. (2020),

Despite the differences and similarities of the industries around the world, construction methods and materials have evolved little or not at all in the last few decades. Instead, the industry is facing a series of shortcomings and challenges such as low productivity, safety hazards, poor project management, and unexpected increases in material costs, powered by some of its characteristics and furthered by its low technology adoption capability and inefficient data management process (Demirdogen et al., 2019; Yousif et al. 2021). The rest of the world is evolving, and the construction industry is not following.

Nowadays, construction project delivery requires the inclusion of smart designs and features consistent with the technological and sustainable needs of both its users and the environment (Cross, 2018; Moeni et al., 2017). These new requirements, together with the aforementioned challenges are forcing construction organisations to innovate and adopt technologies which allow them to meet the new expectations of industry performance (Vellante, 2021; Abusalah, 2021).

In other similar industries such as retail and manufacturing, BD has proven to be a solution to many of their challenges, not only because of the benefits it offers on its own but also because of the support it provides for other essential technologies. In the construction industry, however, there is still much to do to be able to enjoy such benefits. Still, according to Ngo et al. (2020) and Ismail, Bandi et al. (2018), with the increasing amount of data generated by the construction industry and the evolution of data analytics, BD has a considerable amount of potential to create value for the sector.

Although still on early stages of adoption, research of BD in the construction industry is being performed in the context of decision making and safety, to construction project, energy and resource management (Ismail, Bandi et al., 2018). More specifically, practical applications of BD in this industry have been highlighted by different sources such as Wang et al. (2018), Bilal et al. (2016) and Lu et al. (2016), which discuss the application of BD to the improvement of Waste Management. Similarly, Han & Wang (2017), explored the use of BD Processing Capability to improve prefabricated construction project management. Linder et al. (2017), studied the use of BD capability to storage smart building data. And finally, Munawar et al. (2022), who applied BD analytics to process data from drones and computer vision to stablish building quality control and Ara et al. (2020), who used a Gaussian distribution analytic technique to improve scheduling process, just to mention a few. These practical applications of BD technology could potentially solve many of the issues faced by the industry such as improvement of sustainable practices with waste reduction, green building and energy efficiency, and improved quality of the industry's outputs.

The implementation of BD and the shifting paradigm entails a path to a successful adoption that plays a crucial role in implementing the technology. However, the question remains of how construction leaders can embed BD technology within their organisations. While there is an important body of literature on BD applications in the construction industry and the potential to create value, the actual practices, challenges, and integration of the technology into the organisation's culture, system and processes have been vastly excluded.

There is a lack of empirical research evaluating the adoption of BD technology within the construction industry to support sustainable development as well as a lack of guidance or integral framework for BD adoption within organisations, which is the aim of this study. Moreover, there was no evidence discovered regarding the adoption of BD in the construction industry of the Dominican Republic which, according to what was mentioned in the previous section (Section 1.3), is in a privileged position to study the adoption and development of new technologies.

1.3 Research Aim and Objectives

This research aims to develop a framework and readiness tool for adopting Big Data concepts in the construction industry. These instruments will provide standards for adopting the concepts leading to sustainable development.

To achieve the overall aim of this research, the aim has been divided into a set of specific target objectives. The objectives of the study are:

RO1. To understand the benefits of Big Data for the construction industry.

RO2. To explore the understanding of the Big Data concept and its characteristics in the construction industry.

RO3. To investigate the drivers for implementing Big Data in the construction industry.

RO4. To explore the critical strategies for Big Data adoption.

RO5. To examine the challenges when implementing Big Data in the construction industry.

RO6. To develop and evaluate a Big Data Readiness Assessment tool for construction organisations.

RO7. To develop and evaluate a framework for implementing Big Data in the construction industry.

1.4 Research Questions

Given the research background, justification, aim and objectives, the research questions are as follows:

RQ1. What is Big Data and what benefits would it provide to the construction industry?

RQ2. What is the understanding of the construction industry about the Big Data concept, its relationship with the construction industry, and its characteristics?

RQ3. What are the drivers that impulse the implementation of Big Data in the construction industry?

RQ4. What are the key strategies for implementing Big Data in the construction industry?

RQ5. What challenges do organisations and the construction industry face when adopting Big Data?

The research questions and objectives mentioned above are linked in the matrix shown in the table below (Table 1.1).

Table 1.1: Traceability matrix of the research objectives, research questions, analysis approach and chapters addressed.

Aim	This research aims to develop a framework for adopting Big Data concepts in the construction industry. This framework will provide guidelines for adopting concepts leading to sustainable development. To achieve this aim, the following objectives have been identified.				
No.	**Research Objective**	**No.**	**Research Question**	**Chapter Addressed**	**Research Technique for Data Collection**
RO1	To understand the benefits of BD for the DR's construction industry.	**RQ1**	What is BD and what are the benefits that it would provide to the construction industry?	**Chapter 2**	Systematic Literature Review
RO2	To explore the understanding of the Big Data concept and its characteristics in the construction industry.	**RQ2**	What is the understanding of the construction industry about the Big Data concept, its relationship with the construction industry and its characteristics?	**Chapters 3, 4 and 5**	Semi-structured Interviews
RO3	To investigate the drivers for implementing BD in the construction industry.	**RQ3**	What are the drivers that impulse the implementation of BD in the construction industry?	**Chapters 3, 4 and 6**	Semi-structured Interviews
RO4	To explore key strategies for BD adoption.	**RQ4**	What are the key strategies for implementing BD in the construction industry?	**Chapters 3, 4 and 7**	Semi-structured Interviews
RO5	To explore the challenges when implementing BD in the construction industry.	**RQ5**	What challenges do organisations and the construction industry face when adopting BD?	**Chapters 3, 4 and 8**	Semi-structured Interview
RO6	To develop and evaluate a Big Data Readiness Assessment tool for construction organisations.	BD Readiness assessment tool		**Chapters 3, 4 and 9**	Systematic Literature Review and Semi-structured Interviews
RO7	To develop and evaluate a framework for implementing BD in the construction industry.	Framework		**Chapters 3, 4 and 10**	Systematic Literature Review and Semi-structured Interviews

1.5 Research Design

Due to the unexplored nature of the study, the research methodology followed a pragmatic approach. For this same reason, the chosen method for the research was qualitative. The primary data collection followed the same methodology. The secondary data collection was based on a systematic review of the literature.

The data was collected using non-probabilistic sampling based on the literature findings which showed that the company's size influences its ability to implement new technologies such as BD. The size of the company and the position/experience of the interviewee were the factors considered when establishing the sample. Semi-structured interviews were selected as the data collection tool, and thematic and content analysis were chosen to acquire in-depth knowledge from the interviews. Finally, a framework and readiness tool were developed as the output of the research findings. A summary of the methodology is presented in the following table (Table 1.2).

Table 1.2: Summary of the research methodology.

Research Classification	Exploratory study
Research Philosophy	Pragmatism
Research Approach	Inductive
Research Methods	Qualitative
Research Strategy	Grounded Theory
Data Collection	Systematic literature review, Semi-structured interviews
Sampling Methodology	Non-probabilistic
Number of Participants	21
Data Analysis	Thematic Analysis, Content analysis
Research Outputs	• The levels of awareness of BD in the construction industry of the Dominican Republic. • The key drivers that have fuelled the need for implementing BD within the construction industry of the Dominican Republic. • The key strategies for implementing BD in the construction industry of the Dominican Republic. • The key challenges that the construction industry of the Dominican Republic currently faces regarding the adoption of BD. • An organisation readiness assessment tool for adopting BD in construction organisations. • An integrated framework for BD adoption within the construction industry.

The outcomes of the study have been published in three peer-reviewed journal papers and conferences attended by academics and practitioners. This process allowed for the enhancement and improvement of the research techniques used in this investigation.

1.6 Scope and Limitations

Despite the innovative insights provided by this research, it still has some limitations:

- Given the exploratory nature of this research, its findings are only tentative and of limited value for the purpose of generalisability. Furthermore, these results are limited to the Dominican Republic's construction industry. As such, the level of generalisability outside of this context must be considered. However, the similarities between the construction industry in most developing countries could also render the findings obtained in this research valuable for them.
- Given how the research focuses on the construction industry, the results obtained may not be comprehensive to other industries involving different activities and operations, except for the readiness assessment tool, which has been purposely left with a certain degree of generalisation to be applicable in other areas.
- The systematic literature review adopted for this study is limited to peer-reviewed journals, conference articles, reports, books, and technological articles in English. Therefore, it should be acknowledged that this research might be missing out on some studies in other languages that could be important that should be considered in future studies.
- The research explored BD's awareness drivers, strategies, challenges, and critical success factors. The results based on the data gathered from the participants within 19 different organisations might not apply to other organisations within the sector, especially the ones outside the specified characteristic of being able to invest in innovative technology. Therefore, it is recommended that further studies could be carried out using case studies to provide a more in-depth understanding of the elements influencing BD adoption in the sector.
- The data collection process was built on the assumption that the participants had experience implementing technological developments within their

organisations, which was not always the case. However, to reflect the industry's current status, it was necessary to consider all inputs.

- The proposed framework for adopting BD and the BD readiness assessment tool were both evaluated by experienced professionals from the Dominican Republic construction industry. They have not been tested within an organisation.

1.7 Structure of the Thesis

This document has been written using a systematic structure to allow the reader to follow the flow of information logically. This will enable an understanding of how the research objectives were achieved. The thesis starts with this introductory section in Chapter 1 and finishes with the conclusions and recommendations in Chapter 11. To begin understanding the structure of this thesis, Figure 1.1 shows a visual representation which indicates the organisation of the thesis.

Following the summary of the structure of this thesis, a more detailed explanation is provided below:

- **Chapter 1** discusses the background and justification of the study. It presents the research aim, objectives, questions, and methodology. The chapter also discusses the study's contribution to knowledge, scope and limitations, and this outline of each chapter.
- **Chapter 2** reviews the relevant literature regarding the concept of big data and its characteristics and benefits. The chapter is then directed towards the applications of the technology in the construction industry and finalises with an overview of the Dominican Republic as the focus of this investigation.
- **Chapter 3** explores the theoretical background of the study. Theories such as situational awareness, technology-organisation-environment (TOE) and organisational change management are explained within this chapter.
- **Chapter 4** discusses the methodological approach used to achieve the study's aim and objectives. The chapter discusses the selected strategy, the sampling method, data collection, and the selected data analysis methods. Moreover, the chapter highlights the steps taken to conduct the research.

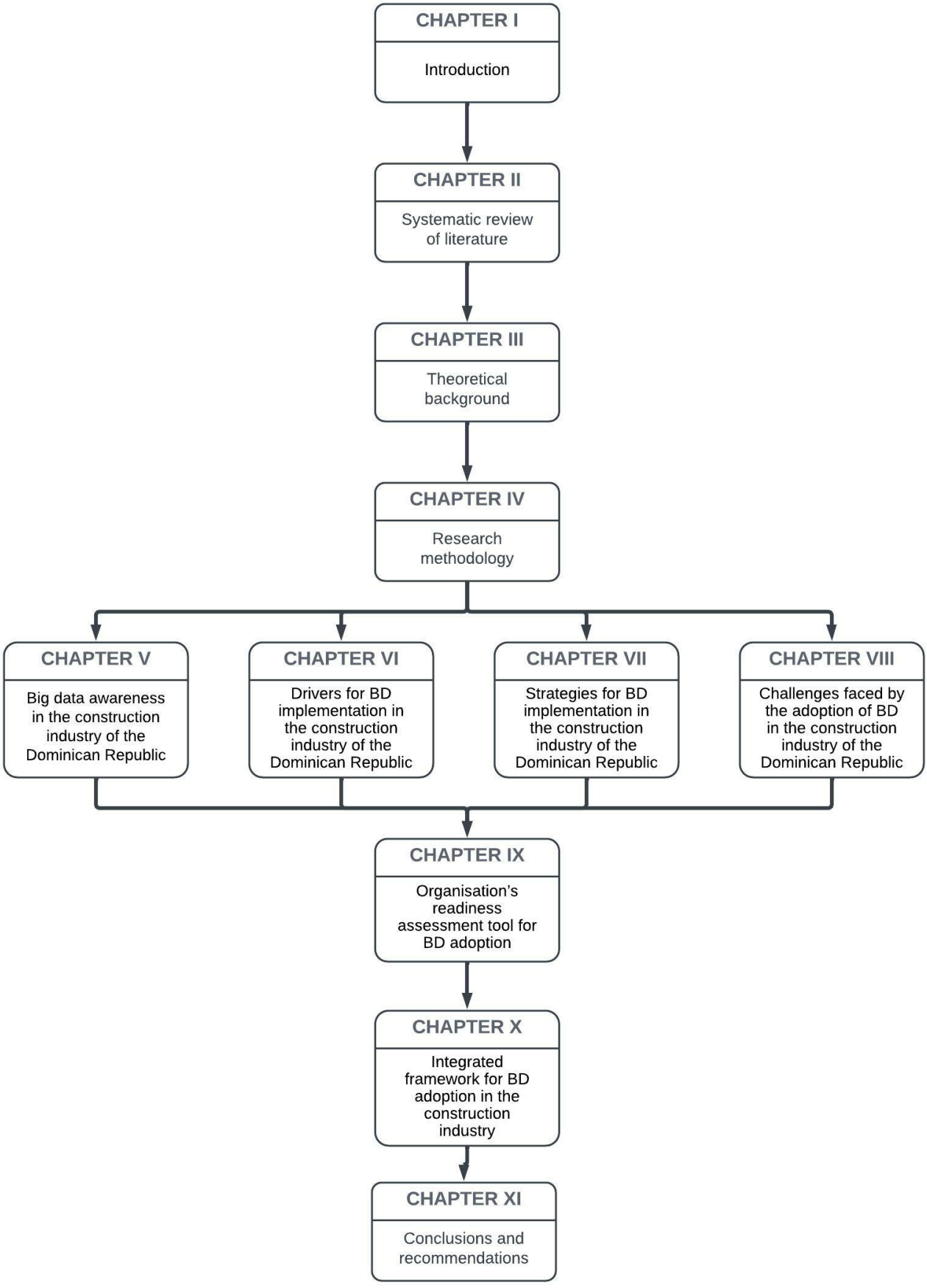


Figure 1.4: Thesis structure

- **Chapter 5** highlights the level of awareness of BD and its characteristics in the Dominican Republic's construction industry. The findings are discussed against the relevant literature. This chapter addresses the second research objective (RO2) and answers the second research question (RQ2).
- **Chapter 6** explains the key drivers pushing for the adoption of BD in the construction industry. The findings are discussed against the relevant literature. This chapter addresses the third research objective (RO3) and answers the third research question (RQ3).
- **Chapter 7** explores the key sustainability strategies for BD implementation in the construction industry. The findings are discussed in the context of the relevant literature. This chapter addresses the fourth research objective (RO4) and answers the fourth research question (RQ4).
- **Chapter 8** discusses the challenges inhibiting the adoption of BD in the construction industry of the Dominican Republic. The chapter addresses the fifth research objective (RO5) and answers the fifth research question (RQ5).
- **Chapter 9** describes the development of the BD readiness assessment tool. The readiness tool was built using the findings of the previous chapters. The chapter addresses the sixth research objective (RO6).
- **Chapter 10** introduces and discusses a strategic framework for successfully adopting BD in the construction industry. The findings from the previous chapters were considered in the development of the framework. The developed framework provides a better understanding of the driving and restraining forces for adopting the technology. This chapter addresses the seventh and last research objective (RO7).
- **Chapter 11** reports the conclusions and recommendations obtained from this investigation. It summarises the key findings of the study and provides recommendations while addressing the aim, objectives, and research questions.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

This chapter reviews the Big Data (BD) literature and its relationship with the construction industry. The chapter is divided into four main sections. The first section examines the concept of BD and its characteristics. The second section explores the general applications and benefits of BD technology. The third section reviews the BD applications aimed at the construction industry. The fourth section provides an overview of the Dominican Republic and its construction industry. Finally, the chapter concludes with a summary.

2.2 The Dominican Republic

The Dominican Republic (DR) is located at the centre of the Caribbean as shown in the figure below (Figure 2.4). It has been considered a democratic republic since 1844. The last official report indicates that it has approximately 10 million inhabitants in a territory of 48,442 square kilometres, the second largest of the region. It occupies the eastern side of Hispaniola Island and it is surrounded to the south by the Caribbean Sea, to the north and east by the Atlantic Ocean, and to the west by the Republic of Haiti (TWB, 2021).

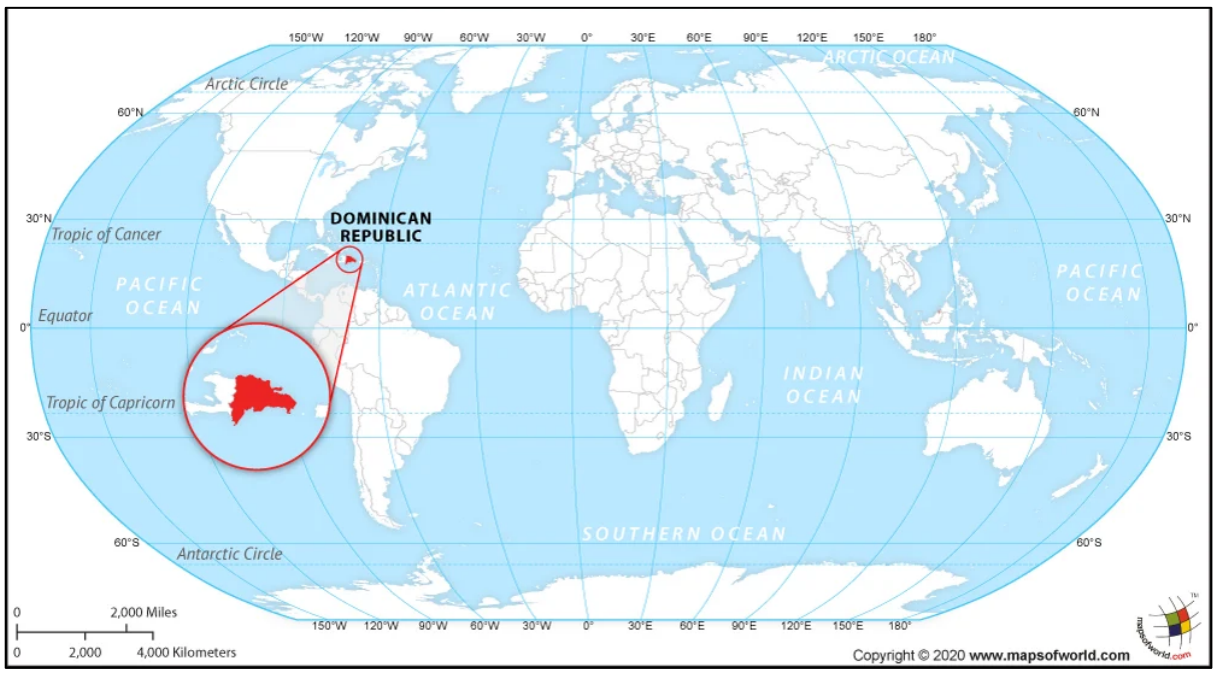


Figure 2.1: Dominican Republic location map
Source: Maps of world

The Dominican Republic is one of the leading economies in Central America and the Caribbean. The industries of tourism, construction, agriculture, telecommunications, manufacturing, and mining are the solid foundations of the country's economy (TWB, 2022). The DR stands out due to its diversity in terms of people, nature and geography since it owns both the highest and lower points in the Caribbean region, the "Pico Duarte" (Duarte Peak) and the "Lago Enriquillo" (Enriquillo Lake). It also possesses flora and fauna totalling 6000 and 7000 species, respectively (MITUR, 2022).

2.2.1 Construction industry in the Dominican Republic

Just as in the rest of the world, the construction industry plays an essential role in Dominican Republic's economy, contributing 12.2% of the Gross Domestic Product in the form of job and income generation, according to the Presidency of the Dominican Republic (2021).

Natural phenomena such as earthquakes and the cyclonic season to which the island is subjected over the year requires that the infrastructure is able to withstand the effects of these phenomena, placing a certain level of responsibility on the Dominican construction industry. The execution of both public and private construction projects to meet the needs in areas such as housing, tourism, and rural development make this industry one of the main players in the Dominican economy (Silverio-Fernandez et al., 2019).

The construction industry is intimately linked to the economic development of the Dominican Republic from the generation of jobs to the infrastructural development of the nation, as well as the improvement of the quality of life through low-cost housing, the infrastructure linked to essential services, and other factors exposed in the national development strategy (MEPyD, 2012).

The construction industry of the Dominican Republic could benefit from implementing BD. Nowadays, the industry faces much of the same general shortcomings of other industries across the word such as low productivity, poor energy and resource management, low technology adoption capability and inefficient data management process (Demirdogen et al., 2019; Yousif et al. 2021). BD could help overcome these issues by applying its visualisation and analysis capabilities in safety, by tracking and visualising site safety conditions and workers behaviours thus improving safety conditions; energy efficiency by enhancing the understanding of building performance

and energy efficiency hence improving energy management; decision making, by improving data visualisation and therefore improving decision making; and integrating other technologies such as IoT devices to monitor progress/performance, time, cost and decision making; and tracking resources and improve its utilisation efficiency (Ismail et al., 2018).

Furthermore, BD could also specifically aid construction by enhancing the industry's sustainability scope. This objective comes aligned with the country's commitment to meeting the 2030 sustainable development goals through the national development strategy mentioned above which even includes specific points to be applied in the industry, such as:

- The overall efficiency of the activity by analysing the data from previous projects and identifying errors that can be prevented in future projects.
- Weather and traffic data analysis for construction planning.
- Smart water meter data analysis to identify new locations for wastewater treatment plants, enhancing effectiveness.
- Governmental database for construction waste management and reduction.
- Tourism data analysis to identify new areas for resort development.

Thanks to the tropical climate of the DR, the construction industry has a stable development throughout the year, unlike many countries where the season's fluctuation influences construction activities. Another advantage is the cheap labour available in the country and the adoption of new tendencies such as construction with metal structures, green buildings, and the application of sustainable practices (ITA, 2017).

2.2.2 The Dominican Republic and sustainable construction

The effects of climate change accelerated economic development and the need for social integration into the management method of governments are issues that have been debated for more than half a century. This integration effort was officially presented as the National Development Strategy 2030 (MEPyD, 2012). The emergence of the NDS 2030 goes back almost four decades before its implementation, starting from the common need for long-term strategies that governments could incorporate into their management policies. The first steps to reach

the goal were taken in 1983 by the United Nations (UN) with the request to make a "global agenda for change." As a result of this petition, a commission of 22 professionals from different areas was formed and after several years of discussions and public hearings, produced the publication called "*Our Common Future"* in 1987. This became the first sustainable development program aimed at policy-making for governments which constitute the UN (Steurer & Martinuzzi, 2007).

Although this document, whose main objective was the integration of social, economic, and environmental policies, served as the basis for the realisation of changes at the governmental level, its adoption encountered many obstacles due to how the government's framework operated. Until then, governments handled their policies in a segregated manner. Each part of the government made its decisions based on its needs without considering the other sectors of the same government. For the next step, implementing the sustainable agenda in three countries, Germany, Norway, and the UK, was taken as a starting point. Some of the sources agree that the evaluation carried out for the implementation of the NDS in these countries served as a basis to determine to what extent the execution of their new policies was based on the sustainable development strategies presented in the 1987 document (Steurer & Martinuzzi, 2007; Tils, 2007: MEPyD, 2012). The results of this evaluation, together with two other documents, became known as the Brundtland Report which, like the first one, favoured a change at the level of the independent structures of governments but not in a general and inter-sectoral manner. Many other countries did not take long to present their development strategies. Still, all of them had the same shortcomings: a lack of monitoring of the established policies and regulations and a lack of adhesion between the sectors of government which hindered the correct implementation of said policies (Meadowcroft, 2007; Bass, 2007).

It was not until five years later in 1992 when the problem of segregation between the different sectors of governments was treated in a particular way due to Agenda 21, a document that urges governments to adopt a national strategy for sustainable development. However, this document did not have a deadline to force the countries to work and deliver a sustainable strategy. Furthermore, it was only taken as a guide by most countries that continued with the same development strategies as before (Bass, 2007). Subsequently, five years later in 1997, it was agreed that by 2002, all countries should develop their own NDS. In 2001, the European Council reiterated this

call to which many of the EU's Member States responded with the submission of their NDS by the end of 2002 (EE UU, 2004).

National development strategies aim to achieve the incorporation of the economic, social, and environmental parts in each area that shapes the government. The guidelines are integral to public policies and how these are carried out (Steurer & Martinuzzi, 2007). Moreover, when analysing the implementation of NDS in Germany, the Netherlands, and the United Kingdom created a base from which the strengths and weaknesses apparent when adopting those policies were determined. Additionally, tangible goals were drawn from this analysis that helped the governments achieve policy integration.

In the specific case of the DR, the policies focused on sustainability evolved within the country until reaching the promulgation of the National Development Strategy as a law in 2012.

2.2.3 National development strategy and the construction sector in the Dominican Republic

There is a significant deficiency of sustainability in the Dominican market, mainly due to the lack of education, the lack of efficient resource management, and the lack of government policies (Fernandez, 2017; Tekton, 2017). Because of this, the NDS includes policies directly and indirectly related to the construction industry. These strategies are distributed between the different governmental sectors in charge of monitoring its implementation. The table below (Table 2.9) presents the governmental policies related to construction in the NDS. Within the listed guidelines, the following may be highlighted as those that most promote sustainable development in construction which seeks to promote the essential principles of sustainability: reduce, conserve, and maintain.

- Conservation of resources.
- Reuse of resources.
- Use of recyclable and renewable resources in construction.
- Considerations regarding managing the life cycle of the raw materials used with the corresponding prevention of waste and emissions.
- Reduction in the use of energy

- Increase in quality in terms of materials, buildings and the urbanised environment.

The representation of these principles in the NDS pursued a positive impact in the construction sector, translated into a reduction in raw material costs, energy consumption, the efficiency of building management during its useful life and, overall, the removal of the negative impacts to the environment that these activities would produce otherwise.

In the same way, the Dominican government has established in its “Sustainable construction strategy,” which is the need for all people involved in an activity to change their way of acting and thinking so then a goal like the one proposed by the NDS is achieved (MINVU, 2013). To achieve this, the country must integrally adopt sustainable construction. Some common aspects, such as efficient water use, raw materials, energy, and soil, are among the critical issues to be addressed. It is clear that although the inclusion of sustainable technologies may represent a more significant initial investment, it can also be recovered in a relatively short time thanks to energy savings, efficiency gains and general wellbeing.

Finally, some applications of BD in the construction industry of the DR could help achieve the goals established in the NDS by improving project delivery, efficiency, resource management and energy efficiency, which in turn increases the chance of meeting the construction-related goals presented in the NDS. Moreover, BD analysis can help monitor and improve the reach of the construction-related policies set by the Dominican government by following the example of the Pakistani government in establishing BOD for transparency (Rabhi et al., 2019; Khurshid et al., 2019).

Table 2.1: Government policies classified according to their relationship with the construction industry

Government Sector	Impact	Construction-related policies or lines of action
Education	Direct	Provide adequate physical infrastructure throughout the national territory
Dwelling	Direct	Planning and development of sustainable human settlements
		Promote the urbanisation of state lands for the development of housing projects
		Promote the development of financing options for builders
	Indirect	Streamline administrative processes related to housing construction
		Establish regulations that guarantee the development of safe, dignified, healthy and sustainable housing
		Relocate settlements at risk
		Regulation of land use
Water	Direct	Develop new network infrastructures that allow for the expansion of the coverage of drinking water, sewerage, sewage treatment and subsoil protection services
		Guarantee the maintenance of the necessary infrastructure for the provision of potable water and sanitation service and the final disposal of resources
	Indirect	Guarantee the timely provision and quality of the drinking water service
Energy	Direct	Plan and promote the development of electricity generation, transmission, and a distribution infrastructure
		Plan and provide the development of a fuel refining, storage, transportation, and distribution infrastructure
	Indirect	Promote the diversification of the electric generation park with emphasis on the exploitation of renewable sources and lower environmental impact, such as solar and wind
Transport	Direct	Develop a prioritisation system for transport infrastructure projects
		Guarantee the quality of infrastructure works through the strict application of regulations
		Develop an efficient and financially sustainable system for the maintenance of transport and logistics infrastructure, including adequate signage

		Develop a provision of infrastructure and logistics services that integrate the national territory and support the production and marketing of goods and services
		Develop road networks that facilitate the integration of tourist centres with each other and with the surrounding communities
	Indirect	Develop the capacities needed to promote and manage public-private participation in infrastructure projects and the provision of transport and logistics services
Environment	Direct	Develop noise and air quality maps and implement pollution reduction plans in collaboration with local governments
		Plan, in a coordinated and integral way, the management of the water resource with the hydrographic basin as a central element for a sustainable allocation to human, environmental and productive use
		Expand and maintain the infrastructure for the regulation of water volume
	Indirect	Conserve and manage the surface and underground water resources sustainably to mitigate the effects of climate change
		Sustainable use of resources
Social	Direct	Creation of mobility and displacement infrastructure for people with disabilities
		Create or prepare municipal spaces for the development of socio-cultural activities and promote their sustained use
		Improve the quality of the community infrastructure

Source: MEPyD (2010).

2.3 Big Data Concept and Characteristics

The first document that used the term Big Data dates back to the mid-1990s (Li et al., 2016). Big Data is used to define a large amount of information in a database which, due to its heterogeneous characteristics, is difficult to manage with traditional data analysis tools (Lu et al., 2015; Miloslavskaya & Tolstoy 2016; Bilal et al., 2016).

Technological development advances at an unprecedented pace. Every day there are new devices that seek to improve quality of life starting from the most basic tasks such as cleaning the home or accessing information to the less trivial, like the efficiency of medical equipment or the reduction of emissions and waste (Lu, 2019; Xu et al., 2020; Lu et al., 2021). A common factor of technological development is the exponential increase in data production (Sayah et al., 2021). The exponential increase, in recent years, has been in the production and transmission rate of the information collected and handled as well as the growth of tools, software, gadgets, mobile and smart devices. IoT has caused the term to regain popularity (Wang et al., 2020; Tamiminia et al., 2020). Thanks to these features, data analysis allows us to determine innumerable characteristics of both the users that produce them and their surrounding environment. Many authors describe Big Data as an activity carried out on a large scale to extract or create “new forms of value” (Keeso, 2014; Lu et al., 2015; Lu et al., 2017). This definition corresponds more technically to Big Data analysis (BDA) since only by analysing the data is it possible to determine if there is any type of value present. Keeso (2014) provides a more straightforward explanation of the subject by describing Big Data as a dataset or database whose volume exceeds the capacity of traditional tools for their management in terms of capture, storage and analysis.

The definition of BD is often confused with the Big Data Analysis definition. This happens because the concept of Big Data is often identified as something abstract rather than something tangible and specific. It is necessary to emphasise that Big Data is a database formed by two aspects that complement each other: Big Data Engineering (BDE) and Big Data Analytics (BDA) (Bilal et al. 2016).

- BDE is the part of Big Data that is responsible for providing support for data processing activities as well as the capacity to store it. In other words, “the BDE provides the infrastructure to perform the BDA.”

- BDA is the process through which the output is extracted as knowledge or a pattern determination to improve decision-making. In many cases, BDA includes the standard procedures for data analysis but on a larger scale.

Moreover, not all datasets can be considered BD. Sources such as Bilal et al., (2016); Keeso, (2014), and Lu et al., (2015), agree that to be considered BD a dataset must possess certain features. The main characteristics are volume, variety, velocity, and value, better known as the 4V's of Big Data. These features have been widely agreed upon by many authors such as Keeso, (2014), Lu et al., (2015), Chen, (2017), Wu et al., (2016), Bilal et al., (2016), and Ahmed et al., (2022). They can be defined as follows:

- **Volume** refers to the amount of space the dataset occupies. Nowadays, a BD dataset's average size is petabytes (PB) and exabytes (EB) or $1x10^{15}$ bytes and $1x10^{18}$ bytes, respectively. With its exponential growth, this figure is expected to increase to 175 zettabytes (ZB) by 2025 or $1x10^{21}$ bytes (Seagate, 2020).
- **Velocity** refers to the speed with which the data is produced and transmitted. In today's economy, velocity goes hand in hand with real-time which means that the data can be transmitted and analysed while it is generated.
- **Variety** refers to the diversity of ways that the data can be presented. BD today includes diverse sources such as audio, video, text messages, pictures, and numeric data, to mention a few.
- **Value** refers to the quantifiable business benefits resulting from the BD analysis. BD handling requires considerable organisational resources; therefore, the dataset must have a sufficient quality to generate tangible benefits.

Many other features are often assigned to Big Datasets depending on the referred source, elements such as veracity which refers to the accuracy of the data. Validity refers to how relevant is the data according to its intended purpose. Volatility, which recognises the state of constant change of the data. Visualisation, which refers to the capability of visually represent the generated insights. All these characteristics can be often found among the description of the technology (Wu et al., 2016). However, the aforementioned 4V's are the ones generally considered to be the essential aspects and are the ones agreed upon by all sources.

The technology has another classification related to the variety characteristic at a more fundamental level. This categorisation divides BD into structured, semi-structured and unstructured, representing the process that the data must go through to be analysed. The following table (Table 2.1) overviews each category and provides some examples.

Table 2.2: Dataset classification according to its structure.

Type of data	***Definition***	***Examples***
Structured	Easy to search and organise data, usually contained in fixed pre-defined fields like rows and columns.	Financial data such as accounting transactions, address details, demographic information, star ratings by customers, machine logs, location data from smartphones and smart devices, etc.
Unstructured	Data that does not have an associated data model that cannot be contained in rows and columns.	Photos, video and audio files, text files, social media content, satellite imagery, presentations, pdfs, open-ended survey responses, websites, call centre transcripts and recordings.
Semi-structured	Data has some consistent characteristics but does not conform to a rigid structure. This is a mix of the previous categories.	Email messages and digital photographs.

Source: Marr, 2019

The definition adopted in this study of Big Data is a heterogeneous dataset that exceeds the management capability of traditional analysis tools whose analysis uncovers patterns and trends that improve decision-making.

2.3.1 Big Data applications and benefits

Big Data is one of the emerging terms with more presence in today's technological society. Several sources have reported applications in various areas of science and engineering (Rabhi et al., 2019; Wang et al., 2020; Tamiminia et al., 2020). Adopting Big Data (BD) analysis in business and human resources management has positively impacted decision-making processes (Rabhi et al., 2019). Big Data works as a solution for the "what to do" question due to the ever-growing volume of information produced every second, and it has applications across a range of business sectors.

Fields such as healthcare, public sector administration, business, and manufacturing among others have taken advantage of the BD development wave present in the last couple of years (Chen et al., 2020; Wang et al., 2020; Rabhi et al., 2019; Tabesh et al., 2019) as shown in the table below (Table 2.2).

Table 2.3: Big Data application across industries

Industry	Applications
Health	Decision-making and medical information management.
Business	Decision-making, market prediction and employee, customer, and transactional data management.
Manufacturing	Industrial automatization, maintenance, and project lifecycle management.
Public Sector	Administration, follow ups and the success rate of policies.
Retail	Future sales predictions based on past trends.
Real state	Estimate property prices based on information from previous years and similar interest rates.

Source: Compiled from Chen et al. (2020), Wang et al. (2020), Rabhi et al. (2019) and Tabesh et al. (2019).

Many fields have adopted Big Data to substitute their outdated systems for data management to better handle and analyse the high volumes of data they produce and possess (Boyd & Crawford, 2012). Confirming the characteristics of massive volumes, various origins and formats, and growing diversity and accessibility in existing geospatial data Tamiminia et al. (2020) demonstrates how very different fields are motivated by the same aspects in terms of BD adoption. Additionally, the increasing amount of patient data in healthcare formed by information assets with a high volume, velocity, value, and diversity through healthcare data resources are considered BD (Chen et al., 2020). BD-based healthcare information systems have been increasing in recent years. It is being adapted to derive important health trends and support timely preventive care mainly because the increasing amount of patient data that can no longer be handled by traditional approaches. In the study titled “Big data management in health care: Adoption challenges and implications” by Chen et al. (2020), it is also noted that electronic healthcare records (EHRs) also use big data analytics for the significant evaluation of diseases and the performance of epidemiological analyses, both of which are critical resources for the management of the industry. Finally, decision-making plays a significant role in all fields; therefore, the data that propels this process needs to be managed with innovative and appropriate tools.

Other areas, such as business and management, rely upon a subjective judgement for decision-making. According to Rabhi et al. (2019), increasingly important decisions depend on hard data. Also, in Human Resources, an increasing rate of organisations are adopting BD, primarily due to the need to manage large volumes of employees,

customers, and transactional data. Meanwhile, BD's application in manufacturing is still in its infancy. Still, at the same time, its application in the fields of natural resource management, industrial automation, maintenance, and product lifecycle management is at an incredible rate (Wang et al., 2020). The following table presents another series of typical BD business applications (Table 2.3).

Table 2.4: Big Data business applications

Business	Applications
Supermarkets	Identify buying patterns and organise their products.
Banks	Analyse customer behaviour and patterns to predict new service solicitudes and detect real-time fraudulent activities.
Streaming Platforms	Analyse viewing history to sort and recommend based on the viewers' preferences.
Pharmacies	Make recommendations by identifying relationships between the patients' medications.

Source: adapted from Tabesh et al. (2019).

Big Data has garnered an incredible amount of attention in recent years. This topic has become the focus of conferences and scientific publications worldwide, becoming a major innovation source for academia, causing a widespread proliferation of research around this topic (Li et al., 2016). Contrary to popular belief that BD is technology oriented to the private industry, the public sector has also started to benefit from its adoption. Public or governmental organisations are among the primary producers of data in large quantities such as geospatial maps, public records of transfers, appointments, financial statements, census data, and environment datasets (Khurshid et al., 2019). Governments have been actively making available to the public large amounts of data without restriction, creating big open data (BOD), a subcategory of BD that shares the same essential characteristics. Among the applications of this BOD is its use for commercial purposes. It allows the public to make more informed decisions and provides real-time data for policymaking to better deal with complex situations.

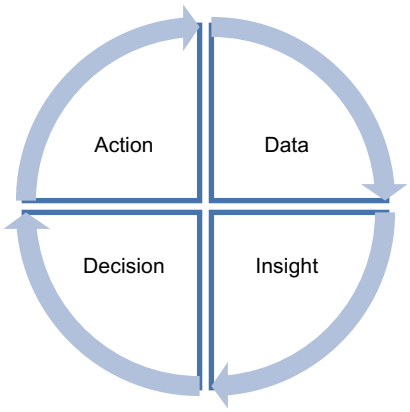


Figure 2.2: Big Data Analysis Process
Source: Adapted from Rabhi et al. (2019).

Moreover, the cyclic process of BD analysis highlighted by Rabhi et al. (2019) represented in the figure above (Figure 2.1) makes the technology an ideal tool to follow up on the implementation of the public policies. Additionally, governments are already using the technology. For example, Pakistan has adopted BOD based on its need for transparency (Khurshid et al., 2019).

Finally, studies agree that adopting BD and predicting relationships, trends, and possible future events to improve decision-making, could result in positive outcomes such as improved financial performance, business optimisation and innovation (Caesarius & Hohenthal 2018; Pigni et al., 2016). Moreover, the adoption's primary driver and benefit is believed to be the promise of “high revenue” when adopting the technology (Raguseo, 2018).

2.4 Big Data linked to the Construction Industry

Despite the many studies looking into the advantages of adopting BD across many industries, little is known about the adoption of BD in construction since the developments that make its use possible in this industry are still in the early stages (Ngo et al., 2020). Still, many sources such as Duggal (2022), Gbadamosi et al. (2020), Goddard (2021), Kim et al. (2008) and Carrillo et al. (2011), Liao et al. (2008), Wong (2020), Morrison (2021), Tyagi (2017), and Cheng et al. (2012) to mention a few, agree that adoption within the industry would produce similar results to those obtained in other disciplines. For instance, in a related field, Neilson et al. (2019) indicated that the traffic data complies with all requirements needed for it to be considered BD. The information from the monitoring equipment and wireless sensors installed to promote

safety and traffic monitoring is already being used to gain insights that enable a more efficient traffic management environment. It also highlights that the projected future of transportation, which is the case of autonomous vehicles, will depend on real-time traffic data that can be delivered more effectively using BD. Along the same lines, other sources have also considered transport which is essential for construction project delivery as a potential beneficiary of BD adoption (Welch & Widita 2019; Li et al., 2020). Additionally, other aspects related to the construction industry, such as the monitoring of critical infrastructures and the geospatial fields used to locate construction projects better, are among the already-known applications of BD in the sector (Filipović et al., 2020).

Sources such as Bilal et al. (2016) and Oudjehane and Moeini (2017) have identified the project schedules, reports, drawings, site images and sensor data, as well as the information and designs coming from the use of Building Information Modelling and the use of sensors and technologies related to IoT as the formats in which construction BD can be present. Furthermore, a study titled “Factor-based big data and predictive analytics capability assessment tool for the construction industry” listed the applications of BD in relation to the project life cycle. These applications have been summarised in the figure below (Figure 2.2). Finally, the analysis also highlighted the decision-making process support as a general technology characteristic (Ngo et al., 2020).

The slow adoption of technological developments characterises the construction industry (Demirdogen et al., 2019; Yousif et al. 2021). In some cases, it requires government support, such as in the case of building information modelling (BIM) in the UK with the BIM mandate (Tuckwood, 2016). There has also been an exponential increase in the use of smart devices within the projects to make some activities within the construction field more efficient (Silverio-Fernandez et al., 2019).

In the same way, the industry has, for decades, been implementing a sustainable approach whose importance rests on the fact that built environment development is one of the main consumers of natural resources (Willar et al., 2021). Because of this, it is necessary to invest in tools that allow industry growth while embedding sustainability.

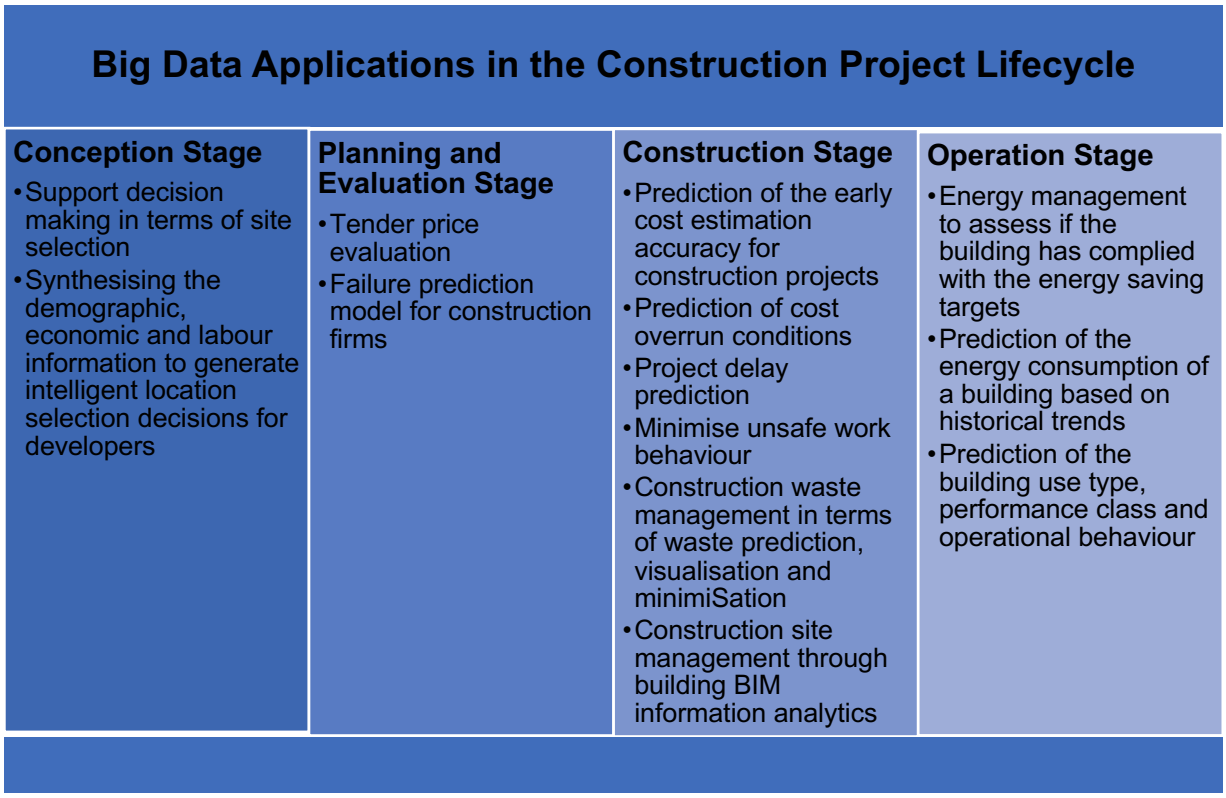


Figure 2.3: Applications of Big Data in the Construction Project Lifecycle
Source: Adapted from Ngo et al. (2020).

The relationship between BD and construction lies in the digital information generated, transmitted, and stored in construction projects (Boyd & Crawford, 2012; Caesarius & Hohenthal 2018; Chen et al., 2020). Furthermore, BD also creates a link between construction and the government by retrofitting and analysing the impacts of the policies that promote the adoption of sustainable practices in the industry, allowing for the adjustment of these policies to ensure better performance and the efficient achievement of the goals set (Rabhi et al., 2019).

2.4.1 Big Data applications in construction

Practical applications of BD in construction have been the target of many recent studies, mainly because of the highlighted potential to improve processes and the outcomes of the industry, which has also been vastly discussed in recent years. Studies such as Munawar et al. (2022) have looked into these practical applications, and which are summarised in the table below.

Table 2.5: Practical Applications of BD in the Construction Industry

Practical Use of Big Data	Source
Use of BD Processing Capability to develop a conceptual framework aimed at improving construction waste management.	Wang et al. (2018), Bilal et al. (2016), Lu et al. (2016)
Use of BD Processing Capability to improve prefabricated construction project management	Han & Wang (2017)
Use of BD Processing Capability to perform profitability analysis of construction projects	Bilal et al. (2019)
Use of BD Processing to develop a BIM augmented framework to improve data visualisation.	Jiao et al. (2014)
Use of BD Processing Capability to improve on construction knowledge maps and determine the factors affecting the utilisation of BD in construction.	Yu et al. (2020)
Use of BD Processing Capability to improve on disaster management by addressing disasters in smart cities through UAVs path planning and 5G communications.	Qadir et al. (2021)
Use of BD Processing Capability to develop a framework for predicting failure of construction firms.	Alaka et al. (2018)
Use of BD Processing Capability to impro on worker safe behaviour analysis by developing a Neural Network for identifying offending drivers.	Asadianfam et al. (2022)
Use of BD Processing Capability to Stablish an energy monitoring service for smart campus.	Liu et al. (2017)
Use of BD to improve on fire incident management by analysing fire-accident factors for construction areas.	Kim & Kim (2018)
Use of BD to improve on smart road management and efficient process management on real-time smart road construction through the implementation of internet of things.	Sharif et al. (2017)
Use of BD Processing Capability for smart city management by using location-aware technologies, open data and 3D urban models to design healthier built environments.	Miller & Tolle (2016)
Use of BD Storage capability to forecast construction project success.	Narayan & Tan (2019)
Use of BD for smart building data storage by creating a platform to storage smart building information.	Linder et al. (2017)
Use of BD Storage capability to design a system for tender price evaluation of construction project.	Zhang et al. (2015)
Use of BD to store data management and monitoring information of bridges.	Jeong et al. (2015)
Use of BD Analytics improving building design and effective performance monitoring.	Loyola (2018)
Use of BD analytics for improving project safety, energy, resource and overall management and decision-making frameworks.	Ismail et al. (2018)
Use of BD analytic capability to expand knowledge base on optimization of big data construction engineering quality management.	Wang et al. (2018),

Use of BD statistical analysis to predict completed construction cost.	Wright & Williams (2001)
Use of BD statistical analysis to visualise accidents in Malaysian construction sector.	Abdullah & Wern (2011)
Use of BD to improve on quality control by inspecting buildings using drones and computer vision to detect cracks and damages.	Munawar et al. (2022)
Using BD to improve the application of Six Sigma for project success	Siddiqui et al. (2016) , Ullah et al. (2017)
Use of Monte Carlo simulation and Gaussian distribution analytic techniques to detect damage in buildings	Lam et al. (2018)
Use of Gaussian distribution analytic technique to improve scheduling process	Ara et al. (2020)
Use of Monte Carlo simulation, Non-Bayesian methods, Correlation analysis and Factor analysis techniques to predict project delays	Shirowzhan & Lim (2014), Sepasgozar et al. (2019) , Doloi et al. (2012)
Use of decision trees and Naïve Bayes analytic techniques to improve decision making process.	Alipour et al. (2017), Baker et al. (2018)

Source: Adapted from Munawar et al. (2022)

In a similar study Bilal et al. (2016) explored other BD applications in construction. These applications explained in a more detailed manner the technical aspects of how BD is being used in the industry, as shown I the table below.

Table 2.6: Technical Applications of Big Data in Construction

Big Data Application	Description	Source
Example of Big Data Processing in Construction	Used BD sorting capabilities to optimise the retrieval of partial BIM models.	Chang & Tsai (2013)
	Development of a specialised big BIM data storage and retrieval system for experts and naive BIM users. The	Lin et al. (2016)
Example of Big Data Storage	Social-BIM to capture social interactions of users along with the building models. A distributed BIM framework, called BIMCloud, is developed to store this data	Das et al. (2014)
	Hybrid data management infrastructure comprised two tiers. One for storing the structured data temporarily for efficiently completing analytical tasks, and a second tier to store permanently the streams of sensor data generated over time.	Jeong et al. (2015)
	Using BD to manage query language to extract partial BIM models.	Cheng & Tang (2013)
	Store BIM data of building models for distributed processing.	Lin et al. (2016)
	Identifying causes of construction delays.	Kim et al. (2008)

Examples of Big Data Statistical Analysis	Learning from post-project reviews (PPRs).	Carrillo et al. (2011)
	Decision support for construction litigation.	Mahfouz (2009)
	Detecting structural damages of buildings.	Jiang & Mahadevan (2008)
	Identifying actions of workers and heavy machinery.	Gong et al. (2011), Huang & Beck (2013)
Examples of Big Data Regression Analysis	Regression for predicting the cycle times of construction operations using least-square-error and least-meansquare. The approach is evaluated on a project installing Viaduct Bridge and is reported to have higher accuracy of predictions.	Siu et al. (2013)
	Linear regression for identifying the delays on construction projects. Their findings reveal that cost and time overruns are frequently occurring delay factors.	Aibinu & Jagboro (2002)
	Relationship between the cause and effect of delays in the Malaysian construction industry using regression models.	Sambasivan & Soon (2007)
	Multivariate regression analysis for predicting the accuracy of estimate during the early stages of construction projects. Estimates are given scores for gaining prediction accuracy. The results reveal that estimate score model is predicting the accuracy with very high significance.	Trost & Oberlender, (2003)
	Multiple regression analysis for predicting the partnering success of contracting parties.	Chan et al. (2004)
	Applied logistic regression analysis to explore the relationship between safety climate and individual behaviour. The results demonstrate the vivid relationship of safety climate and personal behaviour such as gender, marital status, education level, number of family members to support, safety knowledge, drinking habits, direct employer, and individual safety behaviour.	Fang et al. (2006)
Examples using BD Naïve Bayes Classifiers	Presented a Bayesian probabilistic methodology for detecting the structural damages. Bayes factor evaluation metric is computed from Bayes theorem and Gaussian distribution assumption for accurate damage identification. The effectiveness of the proposed techniques is reported for assessing damage confidence	Jiang & Mahadevan (2008)

	of structures over five damaged scenarios of four-storey buildings benchmark.	
	Framework for automated classification of actions of workers and heavy machinery in complex construction scenarios. Employed Bag-of-Video-Features-Model alongside the Bayesian probability for evaluating and tuning action discovery. It is revealed that the proposed approach is capable of identifying several actions in highly complex situations and is faster than the traditional methods.	Gong et al. (2011)
	A Bayesian probabilistic framework is proposed to compute the stiffness reduction studying the effect of severe loading events, namely earthquakes or long environmental degradation, on civil structures. Using simulated data, the proposed approach is found to measure the stiffness accurately. The approaches as mentioned earlier are reportedly revealed as compute-intensive; hence require contemporary Big Data technologies for enhanced accuracy and response.	Huang & Beck (2013)

Source: Adapted from Bilal et al. (2016)

The applications presented in the tables above can help to overcome many of the current issues of the construction industry i.e., poor productivity, lack of energy efficiency, safety hazards, poor project management, and unexpected increases in material costs by enhancing decision-making and improving these processes as explained before.

Finally, according to Ismail et al. (2018), BD could also help overcome issues related to construction management by using IoT devices to monitor progress/performance, time, cost and decision making; Safety, by tracking and visualising site safety conditions and workers behaviours thus improving safety conditions; energy efficiency by enhancing the understanding of building performance and energy efficiency hence improving energy management; decision making, by improving data visualisation and therefore improving decision making; and resource management by using IoT devices to track resources and improve its utilisation efficiency.

2.4.2 BD applications in sustainable construction

Nowadays, BD analytics (BDA) are enhancing the adoption of sustainable practices in the industry by facilitating the efficient use of resources (Keeso, 2014). The number of applications for the results of BDA are countless and applicable to several activities. Sources such as Wang et al. (2018), Bilal et al. (2016), Lu et al. (2016), Asadianfam et al. (2022), Wright & Williams (2001), Abdullah & Wern (2011), and Munawar et al. (2022), to mention a few, consider that Big Data applications in construction could positively impact the industry since it allows for performance assessments, waste reduction, improved energy efficiency, and resource management. Overall, it enables innovation. The above translates directly or indirectly into economic benefits, social gain, and environmental preservation, which is the basis of sustainability.

Subsequently, many other aspects arise from the application of BD such as barriers, challenges, and opportunities. According to the literature, the most important applications are improved decision-making, improved efficiency, waste minimisation, carbon emission reduction, and the optimisation of risk assessments. The related aspects are listed in the table below (Table 2.4).

Table 2.7: Barriers, challenges, and opportunities of BD applications in sustainable construction.

Applications	Barriers	Challenges	Opportunities
Improvement of decision-making	Failure to establish a business case	Lack of economic support	Emerging sources of funding
Improved efficiency	Data reliability	Concept standardisation	Partnerships
Waste prediction minimisation	Bureaucracy	Lack of skills and training	Environment personalisation
Carbon emissions reduction	Creation of a new market with unequal opportunities	Confidentiality, security, and disclosure	Emerging and accessible technology availability
Risk assessment optimisation	Lack of interest and knowledge for its implementation	Lack of government regulation	New areas of specialisation for professionals

Source: Silverio-Fernandez et al. 2019; Ngo et al. 2020; Srinavin et al. 2021; Hwang et al. 2022

Even when all of the leading applications listed can be categorised as positive, many sources have highlighted resistance to change as the main barrier to overcome (Silverio-Fernandez et al. 2019; Ngo et al. 2020; Srinavin et al. 2021; Hwang et al. 2022). However, these elements will be explored more deeply in the following sections.

2.4.3 Benefits of adopting Big Data in construction

In general, the benefits of adopting BD are one of the main drivers for its adoption across all industries. Advantages include improved decision-making (Stannard, 2021), increased revenue (Raguseo 2018), and increased efficiency to mention a few (Neilson et al., 2019; Li et al., 2020). However, in the construction industry, the benefits are not that well known. The following table (Table 2.5) presents a compilation of BD applications and its benefits in the sector. Each application/benefit has been classified into the context of sustainability which is discussed in detail in the following chapter.

Table 2.8: Studies discussing Big Data benefits.

Context	Benefit	Description	Source
Economic	Cost optimisation	Big Data can impact cost optimisation by allowing construction organisations to streamline processes such as product returns, preventative maintenance, and enhanced quality control management. It also allows for the comparison of prices from their material and equipment suppliers.	Duggal (2022) and Gbadamosi et al. (2020)
	Increasing productivity and efficiency	With Big Data analytics tools enabling organisations to process more information at faster speeds, the personal productivity levels of individual workers can increase, and the organisation can gain access to information and insights about its own operations that enable the management to recognise areas where it could be more productive. Developments in the real-time processing of Big Data through streamed analytics enables organisations to become more agile, both in their internal operations and product development, innovation, and speed to market.	Goddard (2021); Gbadamosi et al. (2020); Kim et al. (2008) and Carrillo et al. (2011)
	Potential risks Identification	Businesses require effective risk management solutions to address issues. Big Data plays a critical role in developing effective risk management processes and strategies. Big Data analytics and tools promptly reduce risks by	Duggal (2022); Liao et al. (2008) and Cheng et al. (2012)

		optimising complex decisions for unexpected events and potential threats. This includes more in-depth insights and better data.	
	Accurate budgeting	The more data that becomes available, the better the predictions that can be made for future budget estimates.	Wong (2020) and Morrison (2021)
	Improved pricing	Use a business intelligence tool to evaluate your finances which can give you a clearer picture of where your business stands.	King (2015)
	B2B opportunities	Companies that use Big Data offer supplier networks or B2B communities with higher precision and insights. Suppliers can apply Big Data analytics to evade the constraints they usually face. Big Data allows suppliers to use higher levels of contextual intelligence that is crucial for success.	Duggal (2022)
Environmental	Resource optimisation	Big Data can help organisations optimise the use of resources. By incorporating sensors into their products, organisations can reduce waste, optimise their inventory, and spot defective products, thus increasing profit.	Tyagi (2017)
	Improved environmental risks assessment	BD is also useful for assessing environmental risks by mapping World Resources. This calculates the risks anywhere in the world based on various parameters related to quantity, quality, and other changing regulatory issues in that area. Big Data enables environmental sustainability by helping to understand the demand for energy and food as the world population increases and climate change reduces these resources by every passing year.	Tyagi (2017)
	Understanding operations	BD's usefulness is in its ability to help businesses understand and act on the environmental impacts of their operations. Some of these are within their boundaries while others are outside of their direct control. Previously, this information was	Tyagi (2017)

		dispersed across different formats, locations, and sites. However, now businesses are trying to make out the end-to-end impact of their operations throughout the value chain. This includes things that are outside of their direct control including raw material sourcing, employee travels, and product disposal, to mention a few.	
	Better regulation	BD can be integrated into government policies to ensure better environmental regulation. Governments can implement the latest sensor technology and adopt real-time reporting of environmental quality data. This data can be used monitor the emissions of large utility facilities and if required, put some regulatory frameworks in place to regularise the emissions. Organisations are given complete freedom to experiment and choose the best possible means of achieving the required result. Moreover, keeping a complete track of how various business operations have an impact on the natural world gives way to new and innovative ways for bringing sustainability in an organisation's structure.	Tyagi (2017)
	Environmental footprint improvement	BD can help reduce waste which will improve the industry's environmental footprint. Similarly, as the crews work faster, they'll run fossil-fuel-powered machinery for less time, decreasing emissions. Construction data from past projects can be integrated into BIM technology to more accurately predict the materials and energy needed for a future project.	Wong (2020) and Morrison (2021)
Social	Innovate	The insights gained through Big Data analytics are the key to innovation. Big Data allows you to update the existing products/services while innovating new ones. The large volume of data collected helps businesses identify what fits their customer base.	Duggal (2022)

		Information on what others think of your products/services can help improve product development. The insights can also be used to twist business strategies, improve marketing techniques, and optimise the level of customer service and employee productivity. In today's competitive market space, it is necessary for businesses to implement processes that help track customer reviews, the success of products, and monitor their competitors. Big Data analytics facilitate the real-time tracking of the market and keeps you ahead of any competitors.	
	Better decision-making opportunities	When a lot of information is available in a form that organisations can readily manage and analyse, there is a greater probability of discovering patterns and insights that can inform operational and strategic decisions. Data-driven insights provide a foundation for more informed and reliable decision-making.	Duggal (2022)
	Customer service and experience improvement	Technical support and helpline services powered by Big Data and other intelligent technologies can greatly improve the standard of the responses and follow-ups that organisations can give to their consumers. The responsible use and analysis of customer and transaction data enables organisations to personalise their outreach to individual consumers, leading to a greater engagement with brands and more satisfying user or buyer experiences. Big Data tools can improve operational efficiency and customer interactions while their valued feedback help to collect large amounts of valuable customer data. Analytics can then extract meaningful patterns hidden within the data to create customised products. The tools can automate	Goddard (2021)

		routine processes and tasks, freeing up valuable time for employees which they can utilise to perform tasks requiring cognitive skills. The digital footprints that we leave behind reveal a great deal of insight into customer's shopping preferences, beliefs, etc. This data allows businesses to tailor their products and services to exactly what the customer wants.	
	Improved recruitment and working conditions	Recruiting companies can scan the candidate's resumes and LinkedIn profiles for keywords that match the job description. The hiring process is no longer based on what the candidate looks like on paper and how they are perceived in person. Technology like smart construction wearables and safety management software is quickly gaining traction in the industry, improving overall health and safety.	King (2015), Gbadamosi et al. (2020)
	Allows you to focus on the local preferences	Small businesses focus on the local environment they cater to. Big Data allows you to zoom in on your local client's likes/dislikes and preferences even more. When your business gets to know their customers, their preferences combined with a personal touch means that they gain an advantage over the competition.	King (2015)

Sustainable development is one of the central axes of most governments around the world, and therefore, has been selected as the criteria to classify the aforementioned benefits of BD technology.

2.4.4 Key drivers for adopting Big Data in construction

The motivation behind new technology implementation may vary from organisation to organisation but the critical drivers can be found consistently. Identifying these factors can potentially facilitate the adoption of a new technology that, like BD, is still developing slowly (printed paper). After identifying the possible impact that BD can produce in the construction industry, it is necessary to motivate organisations to adopt the technology, thus accelerating the development process of these new tools.

The key drivers behind the adoption of BD in the construction industry have been identified as follows by different sources (Maroufkhani et al., 2020; Raguseo, 2018; Wang et al., 2020; Boyd & Crawford, 2012; Caesarius & Hohenthal, 2018; Li et al., 2016; Khurshid et al., 2019). Organisations feel motivated to adopt the technology because it offers:

- Relative advantages regarding perception and compatibility by providing high revenue expectations
- New development and partnership opportunities
- Innovative use of software and gadgets
- A solution to the need to manage high volumes of data
- A solution to the need for transparency

Moreover, Madanayake and Egbu (2019) recognised that BD "would support data-driven decision-making for competitive advantage" while also mentioning the "value creation potential from analysis of big data in the construction sector." Likewise, when applying BD to specific construction areas such as waste management, the identified drivers were the solution to the need to understand waste generation (Lu, 2019; Lu et al., 2021; Xu et al., 2020). Increased efficiency in the transport management systems powered by the analysis of real-time data was identified as a critical driver of BD adoption in other construction-related fields as well as the improvement of safety and sustainable conditions within the transport systems (Neilson et al., 2019; Li et al., 2020).

Generally, there is very little evidence of the drivers for adopting BD in developing countries. A study named "Measuring the Big Data readiness of developing countries index development and its application to Africa" explored the willingness of developing countries to exploit the potential of BD (Joubert et al., 2021). There it was established that the islands and coastal nations of the African continent show a greater readiness to adopt BD.

Table 2.9: Identified construction/technology implementation studies in the Caribbean region

Study	Source
An assessment of big data for official statistics in the Caribbean Challenges and opportunities Cardiovascular Risk Factor Calculation View project Technical Report View project	Abdulkadri & Evans (2016)

Evaluating critical success factors for implementing smart devices in the construction industry: An empirical study in the Dominican Republic.	Silverio-Fernandez et al. (2019)
Implementation of smart devices in the construction industry	Silverio-Fernandez (2019)
Implementation of building information modelling in the Dominican Republic construction industry	Silverio Rodriguez (2020)
A framework for UAS Adoption in the Dominican Republic Construction Industry	Reynoso Vanderhorst 2022

Furthermore, in the specific case of the Caribbean region, apart from the studies listed in the previous table (Table 2.6), there is no evidence of there being any literature covering the implementation of new technologies in the construction industry of the Caribbean region.

2.4.5 Key strategies for adopting Big Data in construction

Developing a well-based strategy is crucial when adopting new initiatives and technologies like BD are not the exception (Wattanajantra, 2020). Even though more studies are emerging that are focused on implementing BD in construction, the existing literature does not include the recipe for its successful adoption. Elements such as critical success factors and strategies have not been the focus of these new studies. Due to the lack of sources that recognise the particular case of strategies used for implementing BD in the construction industry, this research will establish a baseline using the critical strategies for implementing smart technologies. The study "Challenges and strategies for the adoption of smart technologies in the construction industry: The case of Singapore" compiled the approaches they believed to be essential to achieve this goal (Hwang et al., 2022). These strategies have been classified into relating to two main areas: government-oriented and organisation-oriented policies which are presented in the table below (Table 2.7).

Table 2.10: Strategies to promote the adoption of smart technologies

Government-oriented strategies	**Organisation-oriented strategies**
Training of a skilled workforce	Communication and change management
Government incentives	Partnership
Establish standards	Top-down leadership
Showcase of a successful case study	Clear organisational structure
Promoting knowledge management for smart technologies	Staff training and development

Source: Adapted from Hwang et al. (2021) and Ngo et al. (2022)

The strategies identified in the study mentioned above serve as a point of comparison for the primary data collected during this investigation into BD in the construction industry.

The adoption of BD in construction depends on several factors. Essential elements such as the investment cost, implementation time, and staff training influence the decision of whether to adopt the technology or not (Chuah & Thurusamry, 2021). Another possible solution to these issues is that organisations can resort to importing digital technology experts to provide the skills required to manage the new technologies or tools. Bhat (2020) also goes a little further to suggest that outsourcing this type of work can result in new partnerships between construction and IT organisations. But then there is the debate on whether it is easier to bring technology experts in from other areas or if it is more feasible to train current employees to use the new technology. The first option would mean training the experts in the technical and essential knowledge of the sector so then their function adapts to the needs of the organisations in the construction industry which might not be achievable or require more effort than the second option.

2.4.6 Key challenges faced by Big Data adoption in construction

It is essential to overcome some of the challenges encountered to close the gap between the promise of a technology and its achievement (Leonard-Barton & Kraws, 1985). Each implemented change, regardless of whether it is at the organisational or industrial level, brings in challenges. In this case, the implementation of BD in construction companies and the industry is not an exception (Baig et al., 2019; Small, 2019).

So far, the challenges experienced by industries with more experience in BD adoption have been summarised in the table below (Table 2.8). These challenges are usually divided into two: industrial and organisational challenges, the former referring to the general problems that industries face when adopting BD and the latter referring to the specific issues faced by the sampled organisations. The following table was compiled based on the analysis of the following sources: Chuah & Thurusamry (2021), Gohil et al. (2017), Balti et al. (2020), and TatvaSoft (2021).

Table 2.11: Big data challenges faced at industrial and organisational levels.

Industrial challenges		Organisational challenges	
Data privacy, governance, and compliance issues	The questions raised around the data sources and their use.	**Managerial challenges**	Organisations fail to treat BD as an ongoing exploration project and instead approach it as a time-limited project.
Defining what BD is and how it can help businesses	The lack of a homogeneous concept makes understanding the technology complex.	**Economic challenges**	Most companies face a lack of budget, time, and the resources necessary to implement BD.
Integrating legacy systems with BD technology	How to avoid data loss when upgrading or transferring to a new system.	**Data challenges**	Incompatibility with the BD characteristics of volume, velocity, variety, and veracity.
Lack of BD skills	Skilled BD analytics workers are hard to find due to skill shortages.	**Data processing challenges**	Any difficulties arising as part of the gathering, pre-processing, or processing stage, as well as the analytical tool selection.
Cost of BD tools	The cost of the infrastructure needed to capture enormous volumes of data is too high.	**Infrastructure management challenges**	The infrastructure management challenges refer to the problems generated from the selection and cost of the instruments needed to perform the analysis.
Complex technological requirements	The complexity of the infrastructure makes it difficult to obtain.		

Source: Compiled from Chuah & Thurusamry (2021), Gohil et al. (2017), Balti et al. (2020) and TatvaSoft (2021).

While most of the challenges presented above are generated across different industries, they are generally identified in data-driven activities such as banking and retail (Salleh & Janczewski, 2019; Aversa et al., 2021). Challenges such as security concerns and data processing challenges demonstrate a deep understanding of the technology while also showcasing situations they would be faced with when already trying to adopt the technology such as a lack of skilled staff and knowledge of the

complexity of the technological requirements (Bell et al., 2021; Brandín & Abrishami, 2021).

In the case of the other industries that, like construction, are less technologically inclined, there are very few records of the challenges that need to be overcome for adopting BD. In the construction industry, some parallels can be established with the adoption of similar technologies. This is the case of Cloud computing which has comparable requirements to BD and whose implementation would facilitate the future adoption of the technology in the industry (Bello et al., 2021). The challenges that still prevent the industry-wide adoption of this technology are presented next.

Cloud computing in construction

The identified challenges in Cloud computing in relation to construction are:

- Latency: there is no guarantee of a reliable transfer rate and response time in time-sensitive applications.
- Trust, data privacy and security: the lack of clarity regarding the security parameters and the reluctance to share private and commercial information.
- Data availability: the inability to access data due to downtime resulting from the Cloud provider could affect the project's development.
- Data governance: the lack of clarity when determining data ownership and the requirement for data exchange between all stakeholders.
- Poor broadband connectivity of construction sites: the service relies on the uninterrupted availability of internet on site.
- The cost implication of long-term use: over time, the overall cost of the Cloud infrastructure could exceed the users' expectations.
- High chance of scoring dark data: large volumes of storage space are wasted on the data generated by sensors with no meaningful insight.
- Threats of edge computing and other associated technologies: the benefits of edge computing overpower the benefits of centralised Cloud computing, thus deeming the technology obsolete.

When analysing the similarities between the challenges of Cloud computing in the construction industry and the adoption of BD in other fields, it could be established that the shared challenges between the two represent the barriers to adopting BD in

the construction industry, even without specific studies detailing its occurrence. The following figure illustrates the challenges when seeking to adopt BD in the construction industry (Figure 2.3). These challenges reflect the essential elements of the technology implementation that can affect its adoption.

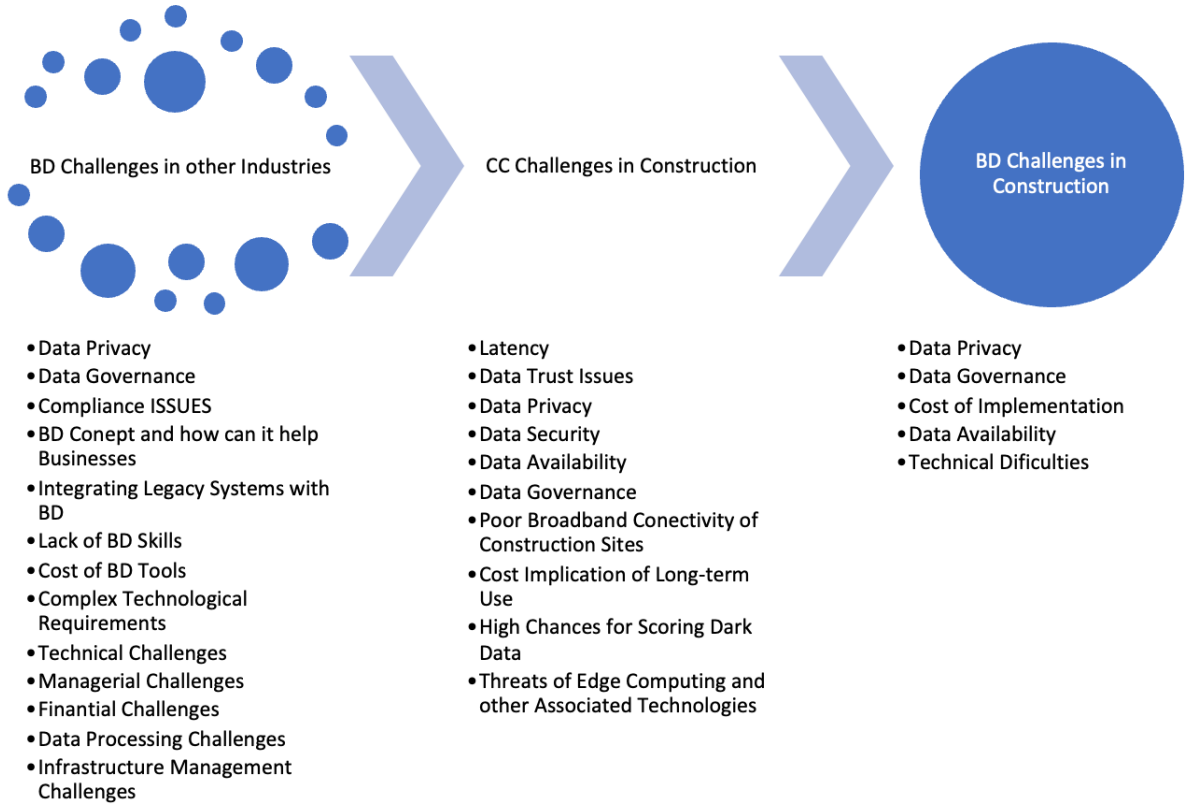


Figure 2.4: Challenges that the adoption of BD could face in the construction industry.
Sources: TatvaSoft, 2021; Chuah et al., 2021; Gohil and Akhilesh, 2018; Shah et al., 2017; Balti et al., (2020); and Bello et al., 2021.

Summary

Big Data is one of the emerging terms with more presence in today's technological society. Several sources have reported applications in various areas of science and engineering (Tamiminia et al., 2020; Rabhi et al, 2019; Wang et al., 2020). Adopting BDA in business and human resources management has positively impacted decision-making processes (Rabhi et al., 2019). Big Data works as a solution to the "what to do" given the ever-growing volume of information produced every second. It has applications across a range of business sectors.

After financial services, the construction industry generates the most significant data volume of any sector. A key challenge for the profession is how we use this data to improve our delivery. Despite the promise of artificial intelligence (AI) and the Internet of Things industry, estimates suggest that up to 95% of construction industry data is not used and instead wasted. The literature shows that the construction industry plays an integral part in the economic growth of the countries it is used in (Khan, 2008; Dlamini, 2012). It is one of the main characters in resource consumption, thus there is an ever-demanding need for technology developments. With that being the case, it sometimes falls short of other industries in terms of the implementation of technological developments. Construction methods have barely changed throughout the sector's history.

In contrast, access to resources and materials has varied significantly in recent years, creating the need for change in the management and use of these resources. Technologies such as BIM that promote a more digitally integrated project management system have gained popularity recently since they allow us to visualise and plan the development of construction projects more efficiently (Sarkar & Modi 2015).

Some industries possess a higher success rate when adopting technological developments than others, e.g., the construction industry, which requires more time to make the changes that allow them to keep up with the latest technologies (Silverio-Fernandez et al., 2019). In the same way, many industries have demonstrated the benefits of adopting Big Data. The question arises as to whether these positive results can be replicated in the construction industry. Ngo et al. (2020) explained that adopting BD in construction could produce great value but there are no tools to assess the adoption capacity of construction companies.

This chapter has explored the literature related to BD and its application in the construction industry. With this, the study was able to develop a functional and universal concept of BD that can be adopted throughout the construction industry. Moreover, this chapter explored the perspective of the Dominican Republic's construction industry and supporting laws such as the NDS. The next chapter (Chapter 3) explores the theoretical background supporting this study.

CHAPTER 3. THEORETICAL BACKGROUND

3.1 Introduction

This chapter establishes the theoretical background for the study. The chapter reviews the theories upon which this research is based. Different theories were applied in this study for different purposes. During the data collection, situational awareness was applied to enhance the understanding of the BD knowledge in the DR's construction industry. The results of this analysis are presented in Chapter 5. The readiness assessment tool, which is introduced in Chapter 9 and is also embedded in the framework for BD adoption presented in Chapter 10, was based on the Technology-Organisation-Environment (TOE) framework for adopting technological innovation in businesses. The third and final theory is organisational change management (OCM) which was also applied during the framework development process.

After reviewing the existing literature on BD and its adoption throughout the different industries, it was clear that one of the main issues was the lack of homogeneous definition and description of its properties and characteristics. This situation prompted the need for an additional analysis in order to draw on a better understanding of the data to be collected on the situation of BD in the Dominican Republic's construction industry.

To fulfil RO2, it is necessary to determine and understand the level of knowledge about BD in the Dominican Republic's construction industry. For this, the following questions was designed:

- What is your level of awareness of the "Big Data" concept and its relationship with the construction industry?
- Are you aware of the volume of data produced in a Construction Project and the variety of said data?
- Are you aware of the benefits that result from BD adoptions in other industries?

This open-ended question aimed to explore the knowledge of the participants about BD. Different types of assessment for awareness were explored such as binary and ordinal methods. In the majority, these techniques relate to quantitative assessments.

In turn, the situational awareness model developed by Endsley was selected based on its ability to assess the perception of an element in a specific environment, in this case, BD knowledge in the construction industry. The idea behind this assessment will be explored in depth in the following section (Section 3.2).

Additionally, the TOE framework was selected as the foundation for the development of the BD readiness assessment tool due to its ability to explain and predict the prospect of innovation/technology adoption as it brings both human and non-human factors into the assessment (Awa et. al., 2016). Finally, OCM theory was selected because of its ability to drive the successful adoption and usage of change (or BD adoption in this case) within the business (Stobierski, 2020).

This chapter is comprised of four main sections. Section 3.2 investigates situational awareness as an assessment method. Section 3.3 explores the TOE framework. Section 3.4 examines the concept of OCM. Finally, the chapter concludes with a summary.

3.2 Situational Awareness

The concept of situation awareness (SA) was initially used in military and aviation applications (Stanton et al., 2001). In a study titled "Toward a Theory of Situation Awareness in Dynamic Systems," Endsley defined this concept as "*the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*" (Endsley, 1995). Alternatively, Smith and Hancock also defined this phenomenon as an "*Adaptive, externally directed consciousness that has as its products knowledge about a dynamic task environment and directed action within that environment*" (Smith & Hancock, 1995). Additionally, a third definition gained recognition in the following years. SA was defined in 1999 as "*the conscious dynamic reflection on the situation by an individual. It provides dynamic orientation to the situation, the opportunity to reflect not only the past, present and future but the potential features of the situation. The dynamic reflection contains logical-conceptual, imaginative, conscious and unconscious components which enable individuals to develop mental models of external events*" (Bedny & Meister, 1999). All three definitions were integrated into a systemic approach since they are considered the main definitions of this construct

(Stanton et al., 2001). The following figure shows an adaptation of the situational awareness definition integration system approach (Figure 3.1).

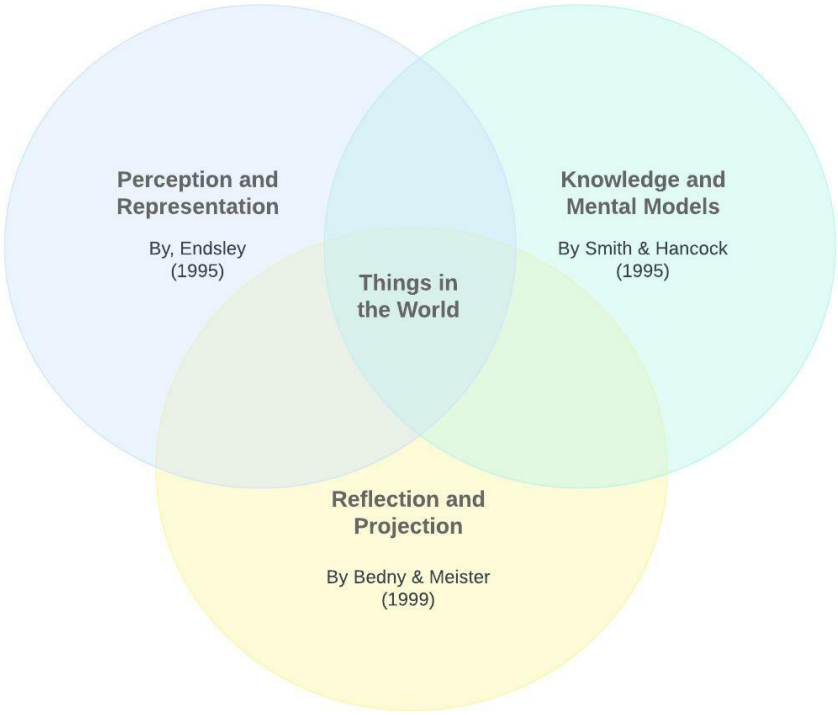


Figure 3.1: System approach integrating the primary situational awareness definitions.
Source: Adapted from Stanton et al. (2001).

These studies highlighted the importance of awareness in human decision-making. Since then, the application of SA can be seen across several industries. In other disciplines such as health, Endsley's model of SA has been employed in areas such as mental health (Moura et al., 2020), thoracic surgery, obstetrics, nursing, and anaesthesia (Dishman et al., 2020). Likewise, the program evaluation field in education has used SA to help improve the decision-making skills of program evaluators (Mason, 2020). Manufacturing has also used SA analysis to reduce the incidence of accidents related to forklift driving (Choi et al., 2020). Since its inception however, the concept has been closely associated with health and safety. It is applied in various environments from flying an aircraft to operating heavy machinery and even driving in heavy traffic and walking (Endsley, 1995).

3.1.1 Measures of situational awareness

Each theory presented its model for assessing situational awareness in a manner that is closely related to its definition (Stanton et al., 2001). Three situational awareness

evaluation models were created and recognised as dominant according to the main theoretical approaches mentioned before. The three main theoretical approaches are presented in the table below (Table 3.1).

Table 3.1: Main research theoretical approaches

Approach	General Description	Source
Information processing approach	The three-level model where SA unfolds as higher-order cognitive processing is performed.	Endsley's (1995)
Ecological approach	The perceptual cycle model is where SA is a dynamic interaction between humans and their environment.	Smith & Hancock (1995)
Activity approach	SA is one of many components of reflective-orientational activity.	Bedny & Meister (1999).

Even when the three definitions can be integrated and are considered close, some specific characteristics can be drawn out when comparing the three approaches, such as:

- **The Three Level Model (Endsley's model)** is prearranged into three hierarchical stages of situational awareness assessment. Each level precedes the next, taking the requirements one step further. In the model, the degree of awareness increases as the information is processed at higher levels from perception, through interpretation, to prediction. Endsley's model is believed to apply to any task that requires track-keeping.
- **The Perceptual Cycle Model** is based on a process-product approach where the process refers to reviewing the state of SA based on perceptual and cognitive activities. Meanwhile, product refers to the state of SA based on the available data and knowledge. The theory explains understanding how the world works leads to expectation which directs behaviour to pursue certain information, creating a ready means of interpretation. This constructs a cyclical process. This model is mainly used to explain human information processing in environments such as engineering control rooms.
- **Interactive Sub-systems Model or Activity Approach:** It is comprised of eight task blocks, each with a specific role. This theory proposes that each

process's involvement depends on the task to be performed and the goal to be achieved. The functions of the model's blocks are summarised as follows:

1) Interpretation of information from the world
2) Conceptual 'image' of information-task-goal
3) Dynamic reflection of the situation and task
4) Comparing motivation and performance
5) Interacting with the world
6) Determining the relevant criteria for evaluation
7) Modify the experience to interpret new information
8) Modify the world model to interpret new information

Additionally, each model has specific strengths that impact the situation in which they can be used. These situations are summarised in the table below (Table 3.2).

Table 3.2: Conditional use of Situational Awareness Frameworks

Framework	Use
Endsley's Model	Functional model for assessing different degrees of insight pragmatically. It offers a direction regarding which types of data individuals might seek when researching situational awareness. However, the embedded-interactive view would suggest that data on the status of the world is required. The cognitive sub-systems view indicates that data about the individual is also important.
Perpetual Cycle Model	Good at explaining the dynamic aspect of situational awareness such as how the momentary knowledge is updated and how the search for information from the world is sought. This presents a high-level view of a person interacting with their environment.
Interactive Sub-System Model	Ideal for considering the underlying functions and how they might interact. This view focuses on the individual to specify the information processing activities inside their head.

Source: Adapted from Stanton et al. (2001).

Although all three approaches have specific views and characteristics, after analysing the impact of the many different factors involved in each framework or assessment system, this study selected Endsley's model for situational awareness to assess BD technology awareness because this framework is recognised as the most generally accepted interpretation of situational awareness (Stanton et al., 2001). The model will be explained in more detail in the following sub-section.

3.1.2 Endsley's model of situational awareness

Endsley believed that SA entails an integrated comprehending of the connotations of information rather than just perceiving the surrounding environment. It also involves understanding the projected future states of the environment that are valuable for decision-making. The framework levels provide an overview of what is expected in each stage. The following figure details the goals of each level of the model (Figure 3.2).

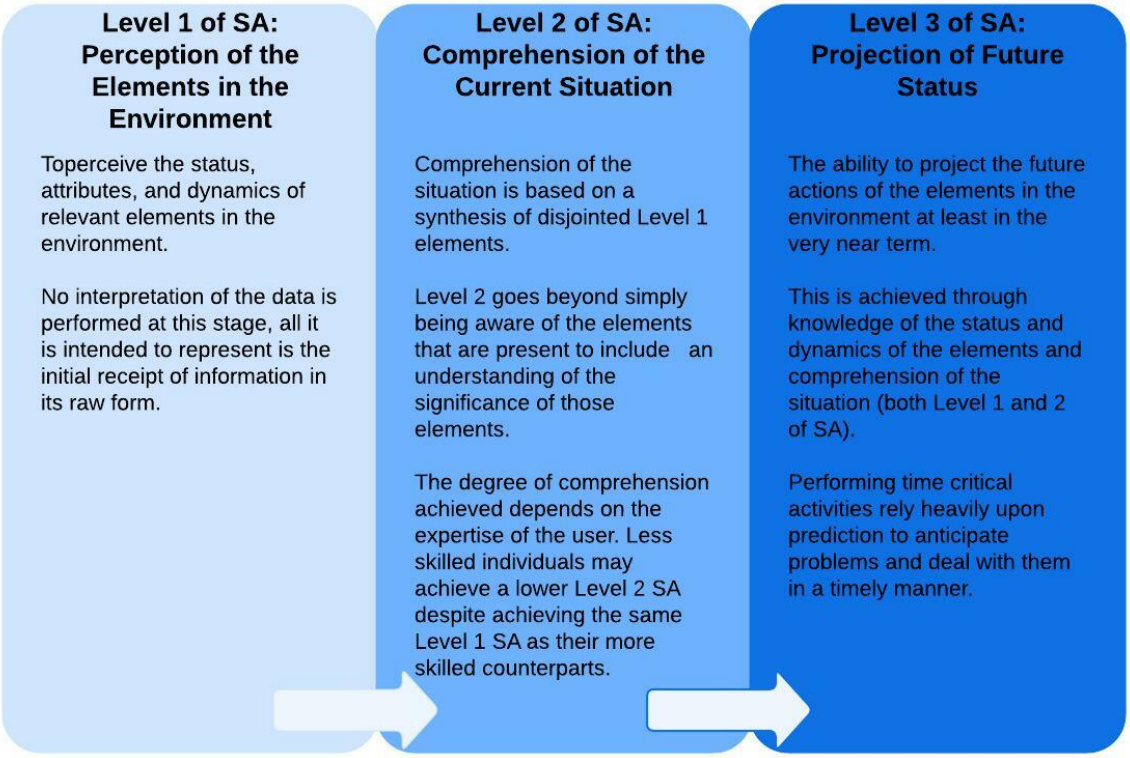


Figure 3.2: Endsley's model of Situation Awareness

Source: Adapted from Endsley (1995), Stanton et al. (2001), and Salmon et al. (2007).

The framework has been adopted as an integral part of the decision-making process in specific situations (Endsley, 1995). In its original study, Endsley explained that SA depends on individual systems and contexts; therefore, understanding the construct rests on the clear interpretation of the things that the operator needs to perceive and understand. The framework portrays SA as a dynamic system embedded within a cognitive model of human activity (Stanton et al., 2001). The model explains that the environment influences SA since abilities, experience, and training impact how the user arrives at a conclusion. Additionally, Salmon et al. (2007) explained that training and experience are critical for achieving SA since it allows for the individual to

recognise vital elements in the environment (level 1), combining these elements to comprehend their meaning (level 2), and producing probable future situations (level 3).

Finally, the Situation Awareness Global Assessment technique was developed based on this model. According to Dishman et al. (2020), the method is considered to be "the only direct and objective situation awareness measurement tool". Here, the three levels are represented in a simplified way.

3.2 Technology-Organisation-Environment (TOE) Framework

The Technology-Organisation-Environment (TOE) framework was first introduced in 1990 by Tornatzky, Fleischer and Chakrabarti in their book "*The Processes of Technological Innovation.*" This describes the process that an organisation must undergo to achieve innovation (Tornatzky et al., 1990; Jere & Ngidi, 2020; Oliveira & Martins, 2011; Baker, 2011).

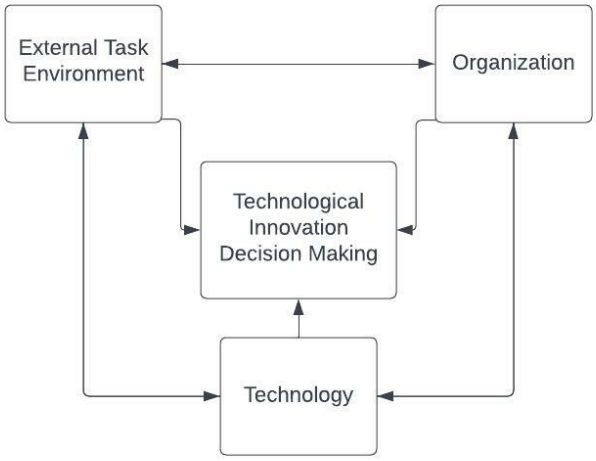


Figure 3.3: Technology-Organisation-Environment Framework
Source: Adapted from Tornatzky et al. (1990)

The TOE framework delivers an outline for analysing the implementation of IT innovations (Oliveira & Martins 2011). According to Oliveira and Martins (2011), other models, such as diffusion on innovation (DOI), have covered the influence of the internal (organisational) and external (technological) factors of the organisation in the adoption of IT innovations. The TOE framework introduced the environmental context which included constrictions and opportunities for technological innovation. In turn,

Baig et al. (2019) and Tornatzky et al. (1990) agreed upon considering that the perceived benefits cannot be received through technological innovation only; instead, it requires support from other areas as the organisation's inner and outer environment directly impacts the adoption of new technologies. Since then, the framework has been widely applied to comprehend the determinants that power an organisation's adoption of new technological innovations (Jere & Ngidi 2020; Baker, 2011; Oliveira & Martins 2011).

TOE conveys theoretical and empirical support for adopting innovations (Tornatzky et al. 1990). The framework includes the three primary contexts: technological, organisational and environmental, though specific sub-constructs identified within the three contexts could diverge through different studies (Jere & Ngidi, 2020; Oliveira & Martins, 2011; Baker, 2011; Tornatzky et al. 1990). The technological, organisational, and environmental contexts will be explained in detail in the following sub-sections.

3.2.1 Technological context

According to Tornatzky et al. (1990), "technological context describes the internal and external technologies relevant to the firm." This context includes all of the necessary resources for its functionality (Baig et al. 2019). It also involves the organisation's technological setting. According to Baker (2011) and Tornatzky et al. (1990), it should consider all relevant technologies including the requirements of existing technologies and any innovations not yet adopted in the organisation. This context refers to the capability of the organisation to make optimum use of the technical infrastructure (Durga & Singla, 2019). Moreover, implementing BD analytics requires organisations to have a structure that allows them to handle and process massive volumes of data in real-time (Kalema & Mokgadi, 2017).

3.2.2 Organisational context

Organisational context involves the firm's resources, setting, and characteristics (Baig et al., 2019; Tornatzky et al., 1990). It refers to the organisation's internal features such as scope, size, and managerial structure (Tornatzky et al. 1990). The context denotes the relationship between the inner characteristics of the company such as the processes, systems, performance, and people, all of which are essential to successfully implement any innovation process (Greeff & Ghoshal, 2004). Furthermore, measuring the organisation's readiness to adopt BD implies analysing

its cultural habits and how they approach problem-solving which will allow for addressing any shortcomings before implementation (Sebastian-Coleman, 2013).

3.2.3 Environmental context

The environmental context engages the organisation's external influences such as industry, government, customers, and suppliers (Baker, 2011; Baig et al. 2019). According to Tornatzky et al. (1990), the environmental context is "the arena in which a firm conducts its business" and refers to external stakeholders' influence on the organisation. This context involves how these factors stimulate innovations" (Baker, 2011). Environmental readiness refers to the organisation's interaction with its external influencers such as suppliers, customers, industry, and the government, all of which will positively or negatively impact the organisation's ability to embrace innovations (Srinavin et al., 2021). The definitions of these measurement units are presented below.

As mentioned above, the main strength of the TOE framework is its adaptability since it allows for personalisation depending on the situation. The following section describes the specific characteristics or sub-constructs selected for this study.

3.2.4 Context sub-constructs selected for this study

The technological context describes the internal and external technologies relevant to the firm. It includes all of the necessary resources for its functionality. Based on this, the following elements were identified as BD technology readiness measurement units:

- Available IT infrastructure describes the necessary components to support the BD process. Both et al. (2013) and Kalema and Mokgadi (2017) agreed that infrastructure plays an essential role in the preparation undertaken for the adoption of new technologies. This is more so in the case of BD since organisations must be able to admit and integrate diverse forms of data from different sources. The elements considered to assess whether an organisation is suitable to adopt BD are:
    - Stable and reliable IT infrastructure (e.g., hardware, software, networking components, an operating system (OS), and data storage).

    - Reliable information communication technology (ICT) infrastructure (e.g., digital telephone network, mobile phones, internet capability, internet servers and fixed broadband, and others).
    - Intelligent system (IS) competence / IT structure.
- Technology assimilation capability refers to the capacity of the organisation to assimilate technology through different processes and levels (de Mattos & Laurindo 2017; Purvis et al. 2001). In this case, the elements to assess are:
    - Perceived simplicity (adequate understanding of BD.)
    - Observability (i.e., the ability to collect data about the program's execution, the internal states of the modules, and the communication between the components).
    - Complexity and tryability (i.e., how easily potential adopters can explore BD).
    - Scalability (i.e., the ability of a hardware/software parallel system to exploit increasing computing resources effectively in the analysis of (very) large datasets).
    - Cohesion (the organisation is able to embed BD at all levels.)
- Availability of BD tools discusses the specific infrastructure needed to support the BD processes. Authors such as Nasrollahi and Ramezani (2020), Mneney and Van Belle (2016), Olszak and Mach-Król (2018), and Baig et al. (2019) recognise the role of the availability of technological tools as an essential part of the adoption process. The elements for the assessment are:
    - Wireless technology.
    - Organisational data environment (e.g., a mechanism to protect data privacy and anonymity).
    - Data security protocols.
    - Data quality and integration.

The organisational context involves the organisation's internal features. Based on this, the elements identified for the BD technology readiness assessment are financial capability, culture, leadership, and the capability of its workforce. According to both Srinavin et al. (2021) and Baker (2011), another essential element to be contemplated in the adoption of innovations, and specifically BD, is the firm's size. This will be discussed later on in the methodology.

Consequently, the elements selected as the measuring units for the tool in the organisational context seek to assess the internal characteristics of the organisation.

- Financial readiness or capability contemplates the organisation's availability of financial resources to adopt and maintain BD and its awareness of the costs and preparedness to face them (Kalema & Mokgadi, 2017). This element significantly influences the BD adoption process because the technology deals with a continuous and exponential increase in its datasets which translates to requiring more upgrades, tools, and resources to function. The elements considered for the assessment are:
    - Adequate financial resources for innovation.
    - Perceived financial readiness.
    - Perceived cost.
    - Cost of adoption.
- Cultural readiness relates to the organisation's ability to distribute resources, stimulate employees, and how it assesses its performance. Kalema and Mokgadi (2017) argue that a culture that allows the integration of its employees' different areas of experience to solve problems will find it necessary to adopt BD and other innovations. The elements considered for the assessment are:
    - Organisational culture.
    - Information security culture.
    - IT expertise.
    - Business strategy orientation.
    - Need change readiness.
    - Decision-making culture.
    - Willingness to change.
- Leadership refers to the support that the organisations receive from the top management when implementing change; it studies how leaders affect their organisation's performance through individual and organisational influence. Thus, they are considered to be agents of change (Bratton, 2020; House et al., 1997). Various sources, such as Nasrollahi and Ramezani (2020), Nguyen and Petersen (2017), and Lai et al. (2018) consider this element to be a critical success factor when adopting new technologies like BD in an organisation. The features considered for the assessment of organisations are:

    - Top management support.
    - Leader's attitude towards change.
    - Management support for BD.
- Staff capability discusses the knowledge and skills that the workforce should have in order to adopt BD. Kalema and Mokgadi (2017) argued that organisations looking to implement BD require capable employees with the necessary skills to engage with the technology, thus deeming this characteristic influential for organisational readiness. The elements considered for BD adoption are:
    - Employer's e-skills.
    - Adequate and up-to-date knowledge/skills of the staff.
    - BD awareness.
    - Technological capability.
    - Training.
    - Cybersecurity awareness.
    - Human resources.

The environmental context refers to how external factors stimulate organisational innovations (Baker, 2011; Tornatzky et al. 1990). It focuses on how external forces can produce a change in businesses and boost innovation. The BD-related sub-constructs identified in this study were the interactions between all external stakeholders of the organisation, i.e., suppliers, customers, industry, and the government.

- Supplier interaction looks into the organisation's relationship with its vendors. Kalema and Mokgadi (2017) established that organisations generally need constant support from their suppliers, especially in the case of BD, since these provide essential procedures and guidance for adopting applications and analytical tools. Mitrega et al. (2017) explained that an excellent organisation-supplier relationship amplifies innovation since the latter constitutes an essential source of resources such as technology, skills, and knowledge. The elements considered for the assessment are:
    - Relationship with their IT supplier.
    - Awareness of digital developments.

- Customer Interaction describes the organisation-client relationship. In construction, this relationship aims to create a partnership between the organisation and its clients. Kalema and Mokgadi (2017) also demonstrated that customer demands influence BD readiness. Generally, people have become more IT knowledgeable and tend to do more of their work online including request submissions to organisations which, in turn, need to provide faster answers to these customers' queries.
    - Customer pressure.
    - Delivery of digital innovation.
    - Information flow is technology efficient.
- Industry interaction looks into the relationship between the organisation and the industry, how the latter can impact the former, and how it can influence the adoption of BD in an organisation by offering competition which can power innovation (OECD/Eurostat, 2019). Kalema and Mokgadi (2017) believe that, on the contrary, BD can help organisations achieve competitiveness by analysing the actions of their competitors in the market. Moreover, Sun et al. (2018) added that BD can help combat the pressure from competitors. The elements selected for the assessment of BD were:
    - Trading partners.
    - Adoption readiness.
    - Market turbulence.
    - Marketing and inventory.
    - Competitive pressure.
    - Supply change connectivity (e.g., orders, tracking, and inventory levels).
- Government interaction focus on the effect of government regulation and the policies exerted on the organisation and its readiness for adopting BD. Government support programmes, public policies, and regulations are considered by OECD/Eurostat (2019) as the drivers of innovation. Sun et al. (2018) agrees with this by reflecting that the support provided by governmental agencies can encourage organisations to adopt BD. Furthermore, government policies can be considered drivers for adoption intention (Lai et al. 2018). In this case, the BD-related elements are:
    - Innovative policies response.

- Engagement with supporting bodies.
- Engagement with and support of the government's laws and policy.

3.3 Organisational Change Management

Businesses face change today more than ever. With the accelerating pace of technology development, organisations are adapting to incorporate these new technologies in their processes. Moreover, growing, downsizing, or restructuring a business to achieve new goals leads to change. Therefore, change has become essential in an organisation's competitiveness (Todnem, 2005). However, according to Graetz et al. (2006), change can become overwhelming for organisations due to its complexity. Because of this, organisational change management has gained weight in the transformation process of businesses worldwide (Odor, 2018; Sarrakh, 2021). According to Sarrakh (2021), it refers to the new state of an organisation that defers from a previous state. This helps the organisation to comprehend the consequences and risks that the change may cause by providing processes, strategies and frameworks for the people and organisations undergoing change. The term is related to an organisational transformation to gain a competitive advantage (Van de Ven & Poole, 1995). Additionally, the term has been defined by Lozano (2013) as the organisation's response to new processes, systems or technological opportunities that can result in financial gains.

According to Odor (2018), environmental dynamism can be a leading cause of change. Following the same line, Sarrakh (2021) believes that the cause of organisational change is closed related to the organisation's drivers. Several sources support the statement that pressure from internal and external sources is the cause of organisational change since it provides an understanding of the need for change (Lozano, 2013; Lewis 2019; Whelan-Berry et al., 2003). Internal and external drivers generate strategic change and transformation within organisations. In the following table (Table 3.3) is listed some of the internal and external drivers which, according to the government of Northern Ireland in its guide "Grow your Business," are affecting organisational change.

Table 3.3: Internal and external factors affecting organisational change.

Internal Factors	External Factors
Raise capital, improve cash flow and the profitability of your business	Address new markets
Improve working practices and processes	React to changes to the product/service demand
Eliminate excess job positions and duplicate management roles	Keep up with new technologies or products
Reorganise internal functions, such as sales and marketing, for efficiency	Mergers and acquisitions
	Joint ventures and business partnerships

Source: Adapted from Northern Ireland business info (2022).

Based on the previous table, it can be determined that there are two types of change in organisations depending on the cause, reactive and planned. On the one hand, reactive change happens in response to an unforeseen event out of the organisation's control. On the other hand, planned change occurs when the organisation wants to achieve pre-defined goals (Northern Ireland business info, 2022). Each of these situations carries a certain level of complexity and uncertainty and could require different resources or a different set of approaches for its execution.

Throughout the years, change has also been classified depending on the magnitude of change. For instance, Miller and Friesen (1984) typed change as either evolutionary or revolutionary; Levy (1986) as either of 1st degree or 2nd degree; Dunphy and Stace (1988) as either incremental or transformational; and Gersick (1991) classified change as either gradual or revolutionary. Within this classification, the authors refer to minor changes, changes in a department or unit changes as the first classification, i.e., evolutionary, 1st degree, incremental and gradual. Meanwhile, the second category corresponds to holistic changes involving all strategic areas of an organisation, i.e., revolutionary, 2nd degree, transformational and revolutionary (Odor, 2018).

Nowadays, there are many different models of change that can be implemented in an organisation, such as:

- **Kurt Lewing Model of Change:** This involves three steps of change where the organisation must recognise the need for change, develop new behaviours and attitudes when implementing the change, and stabilise the change once it has been implemented (Conelly, 2020).

- **Kotter's 8 step change model** describes an eight steps plan for implementing organisational change which involves creating a climate for change, engaging and enabling the whole organisation, and implementing and sustaining change (Kotter, 1996).
- **Action Research Method:** This aims to provide a scientific methodology for producing practical knowledge to be used in the everyday activities of the organisation; this method is formed by four main themes, namely: empowerment of participants, collaboration through participation, acquisition of knowledge, and social change (Odor, 2018; Ferrance, 2000).
- **Organisational Development Method:** This involves various intervention strategies to increase the organisation's capability. These strategies require changing the behaviour of managers and employees, creating an environment where the organisation is more open and adaptive to learning (Mullins, 2007), and developing capabilities to solve problems and react to external challenges (Shvindina, 2016).

However, even when all these models have proven successful when implemented, in reality, change can be particular for each organisation; therefore, there is no one specific method that will ensure success for the process. Because of this, the concept of change management needs to be embedded in the organisational process of change since it will provide a structured approach to planning and supporting organisations to ease the impact change can have on their business. Depending on how change is managed, it can represent either an opportunity for growth or a cause of problems (Northern Ireland business info 2022).

3.4 Summary

This chapter reviewed the relevant literature on situational awareness, technology-organisation-environment (TOE) framework and organisational change management.

First, a model of SA was presented concerning decision-making in complex systems. Building on research in naturalistic decision-making, a person's SA is viewed as a critical focal point of the decision process. This role presents SA as a general construct applicable across various environments and systems.

SA is viewed as a person's state of knowledge about a dynamic environment. It incorporates the perception of relevant elements, comprehension of the meaning of these elements in combination with and relation to operator goals, and a projection of future states of the environment based on this understanding (Endsley 1995).

Additionally, the chapter explored the TOE framework, which delivers an outline for analysing the implementation of IT innovations. The framework explores the three contexts that must be considered for technological innovation, namely technological context, which refers to the capability of the organisation to make optimum use of technical infrastructure. It considers the necessary resources for technology functionality. It also involves the organisation's technological setting. It contemplates all relevant technologies, including requirements from existing technologies and innovations not yet adopted in the organisation.

The organisational context involves the organisation's internal characteristics, such as resources, setting and culture. It refers to the organisation's internal features, such as scope, size, managerial structure, and the relationship between the inner characteristics of the company, such as processes, systems, performance and people, all essential to implement any innovation process successfully.

The environmental context engages the organisation's external influences, such as industry, government, customers and suppliers and their influence on the organisation. Moreover, the specific characteristics selected to assess the readiness of an organisation to adopt BD were also discussed in this chapter.

Finally, the chapter explored the construct of organisational change management, which was generally defined as the organisation's response to new processes, systems or technological opportunities that can result in financial gains. This phenomenon occurs mainly due to environmental dynamism, or the pressure exerted by the internal and external drivers—subsequently, the different models for managing change in organisations were briefly presented.

The following chapter (Chapter 4) discusses the methodology adopted to carry out this study, and the empirical results are explored in the following chapters.

CHAPTER 4. METHODOLOGY

4.1 Introduction

This chapter describes the methodological framework used to direct the research. Implementing various methodologies was crucial to achieving the study's aim of developing the readiness assessment tool and an integrated framework for adopting BD. The chapter begins with an overview of the research process. This was followed by identifying the research philosophy that directed the research and exploration of the research approach, methodology, strategy, and data collection and analysis methods. Next, the steps for research will be explored, followed by the development and evaluation of the BD readiness assessment tool and the integrated framework for BD adoption. Finally, a summary of the chapter is presented.

4.2 Research Process Overview

Research is a systematic process of discovering something unknown (Walliman, 2010). As such, it must follow a methodology, which can be considered the framework based upon which the research is conducted (Brown, 2006). This procedure will be linked to paradigmatic assumptions that should be first, the most appropriate to achieve the objectives of the research, and second, replicable used in other studies of the same nature (Zina 2021; Glatthorn & Joyner 2005). The present study explores the adoption of BD technology within the construction industry of the Dominican Republic. The research process for this study was composed of four main stages: (1) the systematic literature review, (2) data collection, (3) data analysis, and (4) the dissemination of the results. The following figure (Figure 4.1) presents a summary of the process followed by this study.

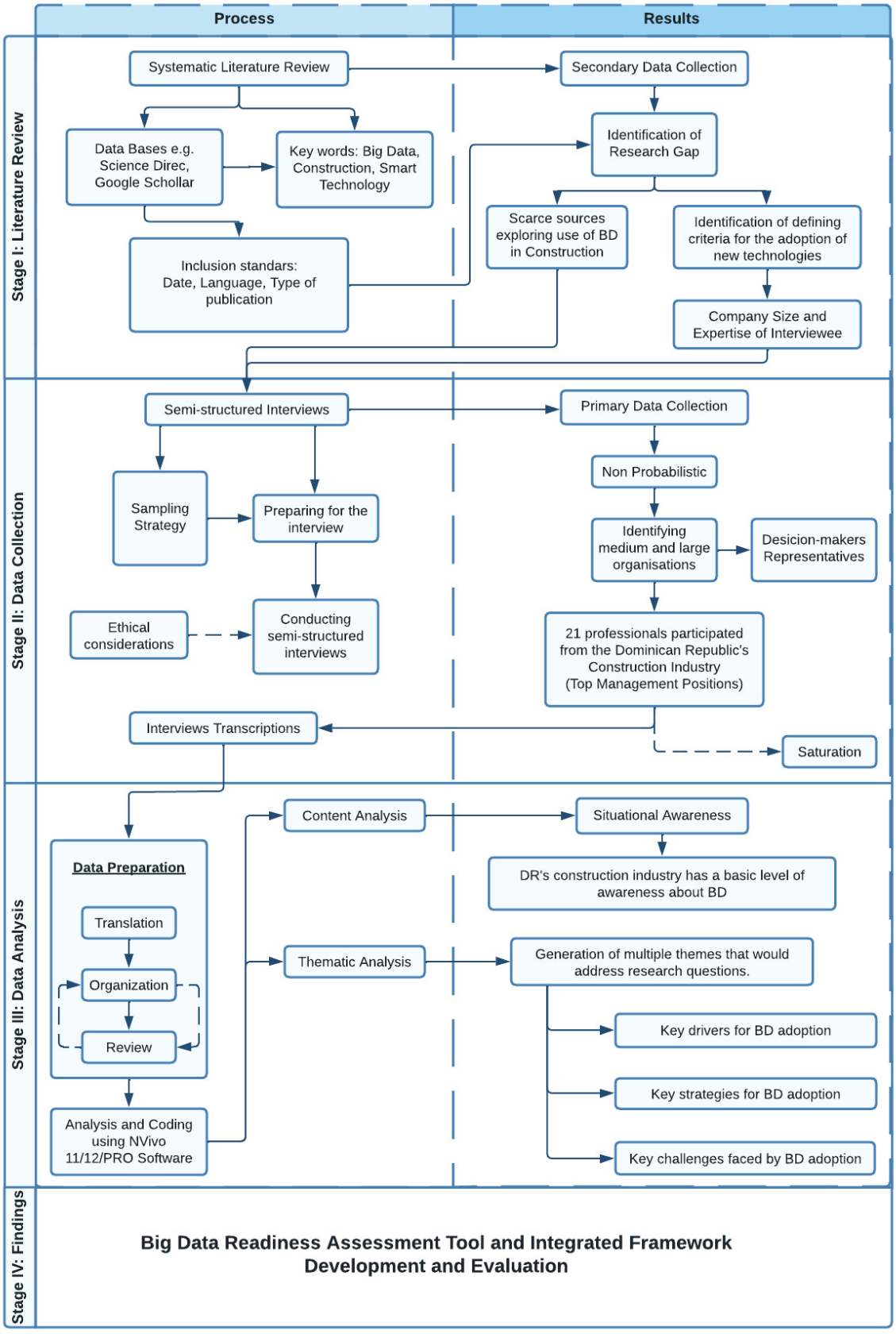


Figure 4.1: Research Process

Following the research design process proposed by Saunders et al. (2015) in its "Research Onion", moving from the general to particular, this study employed an exploratory design since it studied the adoption of BD technology within the construction industry of the Dominican Republic which is a subject characterised by a limited amount of literature. The process of defining the methodology began with the selection of the philosophical orientation. The choice of the pragmatic orientation was based on the unexplored nature of the research problem and because of its flexibility when compared to other ideologies (Strang, 2015). The next step was selecting the research approach, where the inductive approach was chosen for the study since it assumes the presence of a knowledge gap in the literature (Ketokivi & Mantere, 2010). The final stage of the research design was to determine the research methodology. The qualitative method was selected based on the principle of data availability (Kumar, 2014; Creswell, 2017). The chosen method allows for the in-depth exploration of a topic that could not be studied using a quantitative approach (Busetto et al., 2020). Qualitative research explores meaning, purpose, and reality and centres around identifying and understanding participants' experiences, perspectives, and thoughts (Creswell & Creswell, 2018). The choice was made based on the limited resources exploring the relationship between BD and construction, as well as the lack of sources addressing the process of adoption of the technology within the industry.

Furthermore, the research process started with a systematic literature review (SLR) aimed at exploring the relationship between BD and construction as well as the critical elements for its adoption within the Dominican Republic's industry. An example of the steps taken for the research process has been presented in Section 4.5 of this chapter. Specifically, the systematic literature review process is addressed in Subsection 4.5.1. The SLR process provided a starting point for formulating the research objectives.

The data collection process consisted of 21 semi-structured interviews conducted in Santo Domingo, Dominican Republic, between October 2019 and March 2020. The selection of semi-structured interviews as a data collection method was based on the need to obtain consistent and comprehensive data that would allow the subject to be explored in depth (Cohen & Crabtree, 2006). Also, this method is characterised by allowing the capture of the participants' points of view, thus obtaining relevant data that fits the explorative nature of the investigation (DeJonckheere & Vaughn, 2019).

The interviews were directed to the representatives of 19 medium to large companies at the forefront of the market in the country's industry. The representatives, in turn, were part of the decision-making team within the companies. This condition was included to ensure a required level of expertise and knowledge about the protocols necessary for technology adoption and the capability to drive BD adoption in the future.

The interview design was based on assessing BD awareness and exploring the predetermined factors or objectives that would impact technology adoption, such as strategies, drivers, challenges, and critical success factors. The interviews lasted between eleven and thirty-two minutes with all of the required ethical issues considered, such as confidentiality and anonymity.

Various methods were applied to analyse the collected data. Content and thematic analysis were selected to acquire an in-depth understanding of BD awareness and critical elements for its adoption, such as strategies, drivers, and challenges. First, the preparation process consisted of the partial application of Creswell's process for preparing interviews for analysis. The adopted stages consisted of transcribing the audio interviews, followed by the preparation and iterative review of transcripts (Creswell, 2013). Finally, another step was required regarding translating the interviews from Spanish to English and proceeding with the primary analysis process.

On the one hand, the content analysis focused on exploring the levels of awareness. It was complemented by Endsley's model on situational awareness to provide a better interpretation of these results. On the other hand, the thematic analysis focused on exploring the critical elements for BD adoption. These methods involved a six-step systematic process for identifying common ideas, patterns, relevant content, and themes among the analysed data. According to Caufield (2019), they are particularly effective for analysing interview transcripts. To streamline the process of generating codes and themes, this study employed NVivo software (Versions 11, 12 and PRO) which, according to McNiff (2016), is a tool specially designed to analyse qualitative research. Chapters 5 to 10 present a detailed explanation of the findings obtained through the data collection and analysis. A readiness assessment tool and an integrated strategic framework for BD adoption were developed from the results.

4.3 Theory of the Research Methods

The world consists of knowable facts that can be revealed by implementing the correct research methodology, asking the ideal questions and carrying out suitable experiments (Wiskers, 2017). According to Naoum (2013), a research methodology questions and develops the aim and objectives of a research study. It is then vital to ensure that the appropriate research strategy is applied. Additionally, Kumar (2014) explains that the research methodology consists of a detailed plan to be followed during the research journey to find answers to the research questions as validly, objectively, accurately and economically as possible. It is also a way for the researcher to communicate to others regarding the decision on the proposed design, how the data will be collected, the selection of the sample, the analysis of the data and the diffusion of the results. This systematic process aims to discover unknown information (Walliman, 2010).

The research design does not have a universal formula for carrying out research studies. Instead, they are aligned with the research aim and objectives, effectively addressing each research question. According to Chandra and Hareendran (2018), the research design process involves an applied transformation of the research's theoretical angles and allows the researchers to test their hypotheses via practical and empirical methods. In its study titled "*Research methods for business students,*" Saunders et al. (2015) presented a research diagram better known as the "Research Onion" which outlined the different paths or elements involved in a research design, such as the research philosophy, approach, and strategy, and the processes used to collect and analyse the data as shown in (Table 4.1).

Table 4.1: Elements involved in research design

Philosophy	• Positivism • Critical realism • Interpretivism • Postmodernism • Pragmatism
Approach to Theory Development	• Deduction • Abduction • Induction
Methodological Choice	• Mono method quantitative/ qualitative • Multi-method quantitative/ qualitative • Mixed method simple/ complex
Strategies	• Experiment

	• Survey • Archival research • Case study • Ethnography • Action research • Grounded Theory • Narrative inquiry
Time Horizon	• Cross-sectional • Longitudinal
Techniques and Procedures	• Data collection and data analysis

Source: Adapted from Saunders et al., 2015

Nowadays, there are several classifications of research design. According to Bachhofer and Paterson (2000), the most recognised are descriptive, explanatory, and exploratory. Moreover, the literature on research methods suggests there to be three main types of research design; qualitative, quantitative, and mixed (Creswell, 2014; Kumar, 2014). The choice of methods rests on elements such as the level of flexibility, the purpose of the study, and the type and availability of data (Kumar, 2014). In choosing the appropriate research approach, Creswell (2014) proposed the intersection of three elements:

(i) Philosophical worldview assumption,

(ii) Research designs related to the worldview

(iii) Specific methods.

Creswell's (2014) framework served as a guide to choosing the appropriate research design for this study (Figure 4.1). The following sections review these elements and their application to this study.

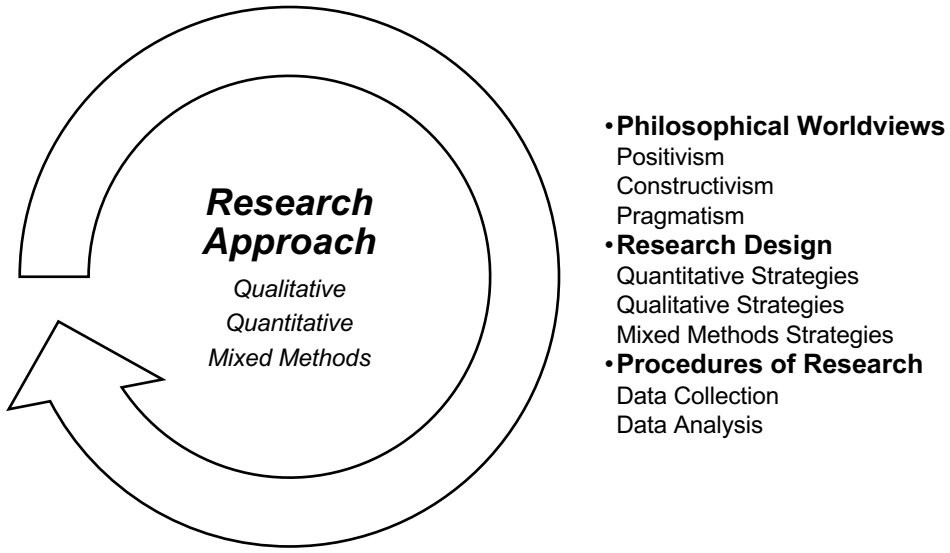


Figure 4.1: Elements conforming the research design
Source: Adapted from Creswell, 2014

4.3.1 Research classification

This section explores the three main classifications of research design, descriptive, explanatory, and exploratory, as presented by Bachhofer and Paterson (2000). The selection criteria for this study will be presented in the following sections.

Descriptive research

Descriptive research answers *what, where, when*, and *how* questions of a phenomenon. According to McCombes (2022), it systematically describes an occurrence, such as population or situation, as accurately as possible. Additionally, Aggarwal and Ranganathan (2019) stated, "It allows the researcher to study and describe the distribution of one or more variables, without regard to any causal or other hypotheses". Furthermore, a descriptive research design provides flexibility in the investigation since the examiner's role is only to observe and measure the variables and not exert any influence over them (McCombes, 2022).

Explanatory research

Explanatory research is a method that explores the *why* of an occurrence when limited information is available (George & Merkus, 2022). It can be considered a "cause and effect model" which provides a better understanding of a topic and predicts future occurrences. Moreover, it is usually considered a type of causal research, since it

identifies tendencies in existing data that have not been previously investigated. According to Dawson (2002), explanatory research studies a problem that has received limited research, focusing on explaining instead of describing the phenomenon.

Exploratory research

Exploratory research aims to investigate a new phenomenon thoroughly. This research design is often qualitative; however, it can also be considered quantitative depending on the sample size (George, 2022). According to Saunders et al. (2007), it differs from explanatory research as it does not lead to conclusive results. More importantly, it aims to understand the overall problem or issue. Additionally, due to its flexible and open-ended nature, it is often referred to as interpretive research or a grounded theory approach (George, 2022).

4.3.2 Philosophical views

Research philosophy can be defined as the diverse systems of principles and suppositions about specific knowledge development (Saunders et al., 2015). Other sources choose paradigms, epistemologies, ontologies, or worldviews to refer to the same term. For instance, Creswell (2014) chose the term worldview and defined it as "a basic set of beliefs that guide actions." Ponterotto (2017) chose the term paradigm instead and defined it as "a set of interrelated assumptions about the social world which provides a philosophical and conceptual framework for the organized study of that world." However, both authors agree that, independently of the name adopted, these beliefs significantly influence the adoption of research strategies (Creswell, 2014; Ponterotto, 2005).

The main philosophical worldviews are positivism, critical realism, interpretivism, postmodernism, and pragmatism (Saunders et al., 2015; Ponterotto, 2005; Kumar, 2014). The following table (Table 4.2) compares the central philosophies and their typical characteristics.

Table 4.2: comparison between the central philosophies and their typical characteristics

Philosophy	Typical characteristics
Positivism	Deductive. Highly structured, large samples, measurement. Quantitative methods of analysis and a range of data can be analysed.

Critical realism	Reproductive, In-depth historically situated analysis of pre-existing structures and emerging agency. Range of methods and data types to fit the subject matter.
Interpretivism	Inductive. Small samples, in-depth investigations, qualitative methods of analysis, and a range of data can be interpreted.
Postmodernism	Deconstructive Reading texts and realities against themselves. In-depth investigations of anomalies, silences, and absences. Range of data types, typically using qualitative methods of analysis.
Pragmatism	Follows the research problem and research question. Range of research methods: mixed, multiple, qualitative, quantitative, and action research. Emphasis on practical solutions and outcomes.

Source: Adapted from Sarrakh (2022)

Positivism

Positivism focuses on acquiring legitimate knowledge through experience and scientific observations (Creswell, 2011). Additionally, in 2014 Creswell expressed that this philosophy embraces “cause-effect” which reflects the need to identify and assess the causes that influence the outcomes of problems (Creswell, 2014). It adheres to the objective belief that a singular reality exists and is driven by immutable natural laws and mechanisms while ensuring the results' accuracy and unambiguity. According to Crotty (1998), in this view, the researcher must remain unbiased and detached from the data to avoid influencing the results.

Critical realism

This philosophy considers social structures real entities, meaning that it sees the organisation and its relationships as structures that might change over time (Bhaskar, 1978). Moreover, Saunders et al. (2015) considered critical realism to be a result of social conditions. It claims that this philosophical view highlights the influence of our senses on how we perceive things. Therefore, our experiences are the result of our sensations, not of things directly. Finally, critical realism considers a two-step process: the thing itself and the sensations it produces, and the mental processing that goes on sometime after the sensation meets our senses.

Interpretivism

Also known as constructivism, this philosophical view assumes that realities are multiple and are constructed in the individual's mind rather than being an externally singular entity (Ponterotto, 2005). Interpretivism relates to the difference between humans and physical phenomena (Goodenough & Waite, 2012). It explores how the people around decode the world. While positivism's ideas are based on observation and numeric measurement of proposed hypotheses, constructivism establishes subjective dialogue interactions with individuals to jointly produce the findings of the problem (Creswell, 2014; Ponterotto, 2005).

Postmodernism

Postmodernism takes the form of the deconstruction of realities. According to Saunders et al. (2015), it centres around language and the power of relations. This philosophical view adopts different perspectives like management, performance, resources, and processes to study the organisation in specific research areas such as management and business.

Pragmatism

Pragmatism insists upon consequent phenomena and results from actions, situations, and consequences rather than the antecedent phenomena adopted in positivism. It believes concepts are only relevant when they support action by considering theories, concepts, ideas, and hypotheses (Saunders et al., 2015). Pragmatism highlights the research question as the most critical determinant of the research philosophy adopted. As such, it considers that selecting one position or the other is unrealistic, providing freedom of choice regarding research approaches and considering any available tools to achieve the desired outcome.

Finally, these philosophical worldviews are aligned with the different research strategies previously mentioned. For instance, quantitative research is developed under a positivist philosophy, while qualitative studies are aligned with a constructivist worldview (Creswell, 2014; Kumar, 2014).

4.3.3 Research approach

Two main approaches are usually used for theory development depending on the researchers' reasoning, namely, inductive and deductive.

Deductive approach

Also called deductive logic or top-down reasoning, Bhandari (2022) defined deductive reasoning as “a logical approach where you progress from general ideas to specific conclusions.” Moreover, the approach involves developing a theory that must be tested rigorously. Subsequently, the results are compared to the hypothesis or premise put forward beforehand; however, if the analysis results are not in line with the hypothesis, the developed theory is wrong (Ketokivi & Mantere, 2010).

Inductive approach

Inductive reasoning is a rational approach to formulating conclusions. Also known as inductive logic or bottom-up reasoning, this is a method of concluding the specific to the general (Bhandari, 2022). The approach acknowledges the gap between the conclusion and its principles, where theory development emerges from the data analysis and is substantiated by the research observations (Ketokivi & Mantere, 2010). Streefkerk (2022) and Woiceshyn and Daellenbach (2018) have explained that the critical difference between the two approaches is that deductive aims at testing an existing theory, while inductive aims at developing a theory. The following figure (Figure 4.2) shows the difference between the deductive and inductive reasoning processes.

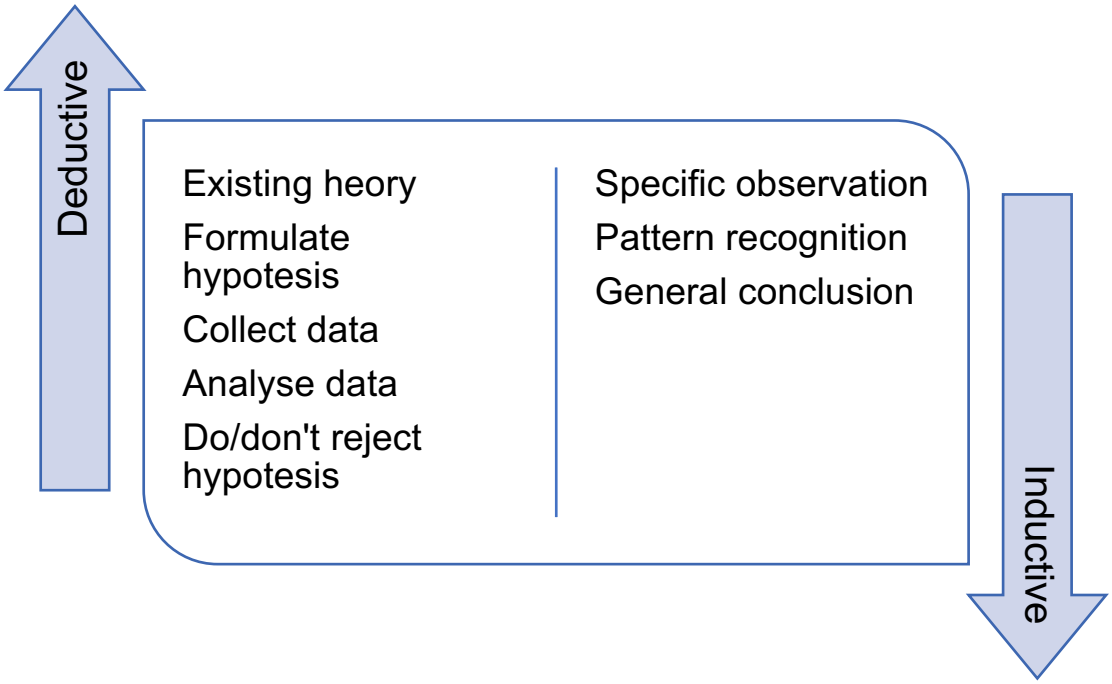


Figure 4.2: Difference between deductive and inductive reasoning process
Source: Adapted from Streefkerk (2022

Abduction approach

Later on, the abduction approach began to gain recognition. This approach parts from the data collection and analysis steps and then formulates the theory. The approach allows the researcher to move from data to argument, alternating between the different steps of the process, as shown in Figure 4.3 (Suddaby, 2006).

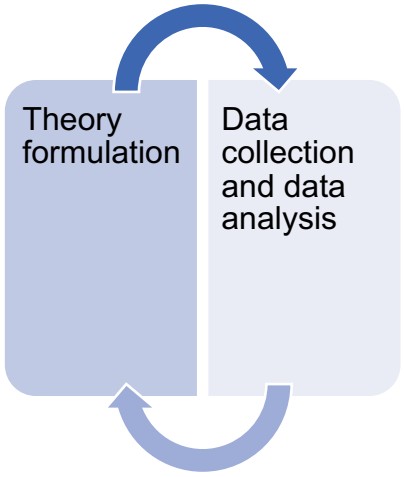


Figure 4.3: Abductive approach reasoning process
Source: Adapter from Suddaby (2006).

The following table (Table 4.3) summarises the different approaches and their characteristics.

Table 4.3: Deduction, induction, and abduction: from reason to research

	Deduction	**Induction**	**Abduction**
Logic	In deductive inferences, when the premises are true, the conclusion must also be true	In inductive inferences, known premises are used to generate untested conclusions	In abductive inferences, known premises are used to generate testable conclusions
Generalisability	Generalising from the general to the specific	Generalising from the specific to the general	Generalising from the interactions between the specific and the general
Use of data	Data collection is used to evaluate propositions or hypotheses related to an existing theory	Data collection is used to explore a phenomenon, to identify themes and patterns, and to create a conceptual framework	Data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework, and to test this through subsequent data collection and so forth

Theory	Theory falsification or verification	Theory generation and building	Theory generation or modification; incorporating existing theory where appropriate to build new theory or modify existing theory

Source: Saunders et al., (2015).

The characteristics presented in the previous table (Table 4.3) constitute a way of identifying when one approach is more convenient than another depending on the individualities of the study to be performed.

4.3.4 Research methods

Qualitative Method

The qualitative approach is based on the philosophy of constructivism which offers an open, flexible and unstructured approach. This method is focused on exploring and understanding the reaction of individuals or groups to a social or human problem (Creswell, 2014). The design of qualitative research aims at discovering rather than quantifying. It highlights the description of the selected sample's feelings, perceptions and life experiences.

This methodology allows for a flexible and descriptive structure of the data and has four types of data collection methods: interview, observation, document, and audiovisual. The most common techniques are interviews, focus groups, and observations.

Moreover, its main attributes are believed to be reducing the use of positivism, accepting postmodern sensibilities, securing detailed descriptions of phenomena, examining the constraints of life and capturing the individual's point of view (Denzin & Lincoln, 2011; Harrison et al., 2017). However, there are questions about its quality, uncertainty, and result standardisation (Hammersley, 2007). Additionally, Bryman (2016) highlighted the limitations of this methodology, such as:

- It is impressionistic and subjective since the findings depend on the researcher's point of view.
- Difficulty replicating it due to the lack of standardised procedures followed.
- Problems with generalisation due to the restricted scope of qualitative investigations.

- Lack of transparency due to a poorly detailed process.

Chowdhury (2015) suggested using different sources and tools to ensure quality to counteract these weaknesses. In turn, Bryman (2016) proposed that findings reliability can be achieved by implementing strategies which make the studies easy to replicate.

Finally, the qualitative methodology provides flexibility for selecting research strategies. The most used designs are narrative research, phenomenological research, grounded theory, ethnography and case studies (Creswell, 2014).

Quantitative Method

In contrast to the qualitative approach, the quantitative approach is based on the rationalism philosophy. Creswell (2014) defined the methodology as a way of testing objective theories by examining the relationships among the measured variables. Additionally, Kumar (2014) explained that achieving the study objectives follows a structured and predetermined set of procedures. This methodology aims at quantifying, rather than discovering, the variation and extent of a phenomenon. According to Kumar (2014), it presents the findings analytically by focussing on the measurement of variables. A qualitative studies' standard data collection methods are performance, attitude, observational, and census data. The commonly used data collection instruments are questionnaires, calibrated equipment, and statistical methods to analyse and reach conclusions.

Additionally, Creswell (2014) highlighted that the main quantitative strategies are survey and experimental research. Unlike the qualitative method, the results of this methodology are easily generalisable since the collected samples are often large and representative, contributing to the findings' validity and reliability (Kumar, 2014). However, this methodology also has its weaknesses, as highlighted by Bryman (2016):

- Failure to distinguish people and social institutions from the world of nature.
- Mistrust due to accusations of an artificial and false sense of precision and accuracy of the measurement processes.
- Due to the low reliance on instruments and procedures, there is an ineffective connection between research and everyday life.
- Lack of dynamic representation of independent variables.

Mixed Methods

The mixed methodology represents a permutation of two or more methods to collect and analyse data about a research problem. Even though the model emerged in 1959 to study the validity of psychological traits, it is still considered innovative (Creswell, 2014). This methodology combines the strengths of the traditional methods to overcome their weaknesses by allowing the researcher to enhance the accuracy of the findings, reconfirm the findings, and create a complete picture of the problem (Kumar, 2014). However, in this case, Teddlie and Tashakkori (2011) identified the following shortcomings:

- Thesis incompatibility due to the differences between the paradigms of the traditional methods.
- Undesired subordination of the qualitative method to the quantitative.
- High resource consumption (i.e., time and money) negatively impacts the study's timeline.
- Quality concerns due to poor writing.

While this methodology is less common, it is starting to catch up with the traditional methods thanks to its flexibility (Teddlie & Tashakkori, 2011).

4.3.5 Research strategies

A research strategy can be defined as the link that ties the research philosophy to the chosen data collection and analysis methods and is considered the steps followed to achieve a specific goal or the plan designed to answer the research questions (Saunders et al., 2015). According to Wedawatta et al. (2011), it aims at providing a global direction for research, including the research process.

The selection of the research strategy depends on the nature of the research problem, that is, the research questions and objectives. Additionally, it is influenced by several aspects such as resource availability (i.e., time and money), access to data sources and efficiency of the data collection process, to mention a few. Saunders et al. (2015) listed the most used strategies nowadays.

- **Experiment:** An experiment can be considered an organised and coherent procedure where one or more independent variables are influenced and assess if a change in one independent variable produces a change in another dependent variable (Surbhi, 2017). The purpose of this strategy is to study the

causal links between variables. The most straightforward experiments involve assessing the link between two variables. In comparison, more complex experiments also consider the size of the change and the relative importance of two or more independent variables. Therefore, experiments tend to be used to answer the '*how'* and '*why'* in exploratory and explanatory research (Saunders et al., 2015).

- **Surveys are** a method for procuring information about a studied variable from the whole population or a fraction of it (Surbhi 2017). This strategy is usually associated with the deductive approach that is used for exploratory and descriptive research. It is often used to answer *who, what, where, how much and how* many questions (Saunders et al., 2015).
- **Action Research** is a strategy that seeks transformative change through the simultaneous process of taking action and doing research, linked together by critical reflection (Reason & Bradbury, 2001). According to Saunders et a., (2015), it focuses on resolving organisational issues such as the implications of change and those who experience the issues directly. Additionally, it relates to the involvement of practitioners in the research. Often the researcher is part of the organisation within which the research and change process occur.
- **Case study:** Creswell (2013) defined case study research as "a qualitative approach in which the investigator explores a bounded system (a *case*) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving *multiple sources of information* (e.g., observations, interviews, audiovisual material, and documents and reports), and reports a case *description* and case-based themes." Moreover, Saunders et al. (2015) explained that contrary to other strategies such as experimental and survey, this strategy involves an experimental study of "a particular contemporary phenomenon within its real-life context using multiple sources of evidence."
- **Ethnography** is a qualitative strategy aimed at studying a group with share elements such as learned patterns of values, *behaviours*, beliefs, and language, and where the researcher then interprets these cultural elements (Creswell, 2013). Saunders et al. (2015) explained that this strategy fits into the inductive approach and stems from the field of anthropology. Furthermore,

Creswell (2013) highlighted some of the principal challenges faced by this type of strategy:

  - The researcher needs specialised knowledge such as a grounding in cultural anthropology and awareness of the meaning of a social-cultural system.
  - It is resource-consuming since the time needed to collect data is extensive, involving prolonged time in the field.
  - Because of its storytelling approach, this strategy is directed toward a limited audience. Also, it may be challenging for researchers who use " normal " writing methods.

- **Grounded theory** is a qualitative research strategy in which the researcher generates a general theory or explanation of a process, action, or interaction based on the opinions of many participants (Creswell, 2013). According to Saunders et al. (2015), in grounded theory, the first step of this strategy is to develop an initial theoretical framework which starts the data collection process. The theory is developed from data generated by a series of observations which then leads to the generation of predictions which are later tested to confirm or refute the predictions. Additionally, Creswell (2013) expressed that in this strategy, theories should be built upon data from the field, especially in the “actions, interactions, and social processes of people.” That way, the generated theory would be based on the elements collected from individuals.
- **Narratives** are believed to be “any text or discourse, or it might be the text used within the context of a mode of inquiry in qualitative research, with a specific focus on the stories told by individuals” (Creswell, 2013). This strategy derives originally from literature but in time, different fields, such as history, anthropology, sociology, sociolinguistics, and education have adopted their own versions. Moreover, this research strategy requires extensive information about the subject. This makes it a challenging approach since the researcher needs to clearly understand the context of the individual’s life.

Finally, in a study titled “Qualitative Inquiry & Research Design,” Creswell (2013) summarised the key aspects of the five research strategies he believed to be essential. Four of these five strategies coincide with the ones previously identified by Saunders

et al. (2015). The following table (Table 4.4), summarises these strategies and their characteristics.

Table 4.4: Most used research strategies characteristics

Strategy	Focus	Type of Problem	Unit of Analysis	Data Collection	Data Analysis
Case Study	Developing an in-depth description and analysis of a case or multiple cases	Providing an in-depth understanding of a case or cases	Studying an event, a program, an activity, more than one individual	Using multiple sources, such as interviews, observations, documents, and artefacts	Analysing data through a description and themes of the case as well as cross-case themes
Ethnography	Describing and interpreting a culture-sharing group	Describing and interpreting the shared patterns found in the culture of a group	Studying a group that shares the same culture	Using primarily observations and interviews, but perhaps collecting other sources during extended time in the field	Analysing data through the description of the culture-sharing group; themes about the group
Grounded Theory	Developing a theory grounded in data from the field	Grounding a theory in the views of participants	Studying a process, action, or interaction involving many individuals	Using primarily interviews with 20–60 individuals	Analysing data through open coding, axial coding, and selective coding
Narrative Enquiry	Exploring the life of an individual	Needing to tell the stories of an individual	Studying one or more individuals	Using primarily interviews and documents	Analysing data for stories, “restoring” stories, developing themes, often using a chronology

Source: Adapted from Creswell (2013).

4.4 Study Research Design

4.4.1 Exploratory study

Previously, the exploratory nature of this research has been highlighted. This nature defined the design of the study. According to Quee (1999), an exploratory design's advantages lie in the ability to explore different perspectives and scenarios of the same problem, facilitating understanding of the phenomenon. Additionally, the author also highlighted the discovery of insights and ideas as the main strength of this type of design. Another advantage of the exploratory design is its adaptability level since it investigates the phenomenon in varying degrees of detail instead of trying to gain final and conclusive results (Saunders et al., 2007). Finally, in line with this study, this type of design fits the setting where there is limited information about a topic, providing a starting point for further studies.

4.4.2 Pragmatic orientation

This study selected pragmatism as the philosophy to follow. This selection was based on a comparison between ideologies, where pragmatism provides more freedom and flexibility. It allows for a wide range of research methods to be applied to address the research objectives and questions and to identify a path for adopting BD technology in the construction industry. In this case, the data collection methodology remains purely qualitative due to the novelty and lack of sources to explore the topic which distinguishes this orientation from a mixed methodology. Furthermore, this orientation focuses on the research problem, placing the research question at the centre of the philosophy, recognising that every method has its limitations and that different approaches can be complementary.

In pragmatism, attention is placed on practical solutions and outcomes rather than abstract distinctions, aligning with the research problem of this study, namely, the adoption of BD in the construction industry. Lastly, pragmatism provides freedom in terms of choosing the methods, techniques and research procedures. It generates practical outcomes that can be easily undertaken and aligned with the researcher's preferences to ensure the research outcomes can be easily assimilated by the industry.

4.4.3 Inductive approach

This study selected an inductive approach based on its ability to provide an understanding of the meanings humans attach to events, thus ensuring a better understanding of the research problem and the current status of BD in the construction industry. The results of the data gathered allowed the formulation of a new theory, expressed in the findings in the form of a framework that guides the industry towards adopting the technology. Additionally, according to Saunders et al. (2015), this approach emphasises and contributes essential elements to address the objectives of this study, such as:

- A clear understanding of the research context.
- The collection of qualitative data.
- A realisation that the researcher is part of the research process.
- Less concern with the need to generalise.

Furthermore, unlike the deductive approach, which requires the formulation of a theory before collecting data and a highly structured approach, which in turn limits how the topic can be explored, this approach allows for more freedom that provides a flexible structure to implement changes of research emphasis as the research progresses.

4.4.4 Qualitative method

During the first stages of this study, it became evident the limited body of literature available about BD and its application in the construction industry. The selection was based on the concept of data availability due to the lack of information on the subject (Kumar 2014). This selection resulted in adopting a qualitative method to carry out this research. The qualitative approach was determined to be the most suitable to carry out the investigation since it allows for the development of a theory regarding the procedures, drivers or challenges involved to properly understand the phenomenon.

Creswell (2013) defined qualitative research as “a situated activity that locates the observer in the world” which means that it studies things in their natural environment and is interpreted through the people's views. This methodology places the researcher at the centre of the investigation through the data collection process.

A qualitative methodology provides a more profound understanding of a subject without the need for massive samples, which aligns with the conditions of this study

which seeks to explore the adoption of cutting-edge technology in an industry that is not very akin to innovations.

4.4.5 Grounded theory

As mentioned in a previous sub-section (4.3.5), the choice of the research strategy depends on several factors such as the research problem, research questions and objectives. It also needs to relate to the research philosophy and approach and reflect the availability of resources. After considering these elements, grounded theory was identified as the most suitable and fits this study's criteria for research strategy.

According to Creswell (2013), a grounded theory study aims "to move beyond description and to *generate or discover a theory*, an abstract analytical schema of a process." The participants in the study would all have experienced the process, and the development of the theory might help explain their practices or provide a framework for further research.

During the literature review, it was identified that technology innovations and, more specifically, the adoption of BD technology depends on two main factors. The first factor is company size since it will influence the capability of investing in new technological developments. The second factor is the support of the decision-makers of the organisations, which influences the adoption process. These criteria were used as a basis to shape the data collection process. Strauss and Corbin (1998) explained that in grounded theory, the development of the theory must be generated based on data from participants who have experienced the process. This aligns with this study which is focused on the opinion of top management decision makers on the construction industry of the Dominican Republic, thus ensuring that they can provide information based on similar experiences.

The grounded theory involves two popular approaches, the first of which is the systematic procedures of Strauss and Corbin (1998), where the investigator seeks to systematically develop a theory that explains the process, action, or interaction on a topic. Moreover, the constructivist approach of Charmaz (2006) is where, instead of embracing the study of a single process or core category, this approach emphasises diverse local worlds, multiple realities, and the complexities of particular worlds, views, and actions.

This study followed the Charmaz approach since it reflects a reality where the development of the theory depends on the researcher's view, learning about the experience within embedded, hidden networks, situations, and relationships, and making visible hierarchies of power, communication, and opportunity (Creswell, 2013). Moreover, Charmaz's approach prioritises an individuals' views, values, beliefs, feelings, assumptions, and ideologies over the research methods.

Finally, Saunders et al. (2015) highlighted the key elements that should be considered when adopting grounded theory:

- Early start of data collection.
- Concurrent collection and analysis of the data (e.g., the analysis of the interview that was conducted completed first before moving on to the next one).
- Developing codes and categories from the data as they are collected and analysed.
- Use of constant comparison and the writing of self-memos to develop conceptualisation and formulate a theory.
- Use of theoretical sampling and theoretical saturation to build theory rather than achieve population representativeness.
- Use of the literature as a complimentary source regarding the categories and concepts emerging from the data.
- Development of a theory that is grounded in the data.

4.5 Research Steps

The research stages are explored and shown in Figure 4.1, representing the research process followed in conducting this study. Stage 1 is the systematic literature review, while stage 2 is the data collection, stage 3 consists of the data analysis, and stage 4 is dedicated to the development and validation of the readiness assessment tool and strategic framework for the adoption of BD in the construction industry of the Dominican Republic.

The data collection and analysis methods and techniques used for this study were (1) the systematic literature review, (2) semi-structured interviews, (3) content analysis,

(4) situational awareness, and (5) thematic analysis. The reasoning behind choosing these methods will be explained in this section.

4.5.1 Systematic literature review

The methodology used for the literature review within this study followed a logical approach similar to the one presented by Snyder (2019), who described the literature review as “a more or less systematic way of collecting and synthesizing previous research.” This technique, when done effectively, can create a well-founded knowledge base and facilitate theory development by combining findings and perceptions from previous empirical findings (Snyder, 2019). Furthermore, the method is a unique way of processing research findings to uncover evidence and areas in which more research is needed, which is critical for creating theoretical frameworks and building conceptual models. However, a traditional literature review can lead the research to flawed assumptions. Consequently, guidelines have been developed for conducting LR and overcoming this issue, such as:

- **Integrative reviews:** These aim to address mature or new emerging topics, as well as to evaluate, critique, and summarise the literature on a research topic so new theoretical frameworks and perspectives emerge. This review methodology requires a more creative collection of data since it seeks to combine perspectives and insights from different fields or research traditions. An integrative review method should generate a new conceptual framework or theory.
- **Semi-systematic review**: This focuses on multidisciplinary topics that are difficult to process with a systematic review, or in other words, where it is not possible to review every single article that could be relevant to the topic. This methodology looks at the progress of a topic over time to identify all potential implications for the studied topic. According to Snyder (2019), this process is useful for discovering themes, theoretical perspectives, or joint issues.
- **Systematic reviews** adopt a replicable, scientific, and transparent process intending to minimise bias through an extensive literature exploration of the existing published and unpublished studies (Tranfield et al., 2003). Snyder (2019) defined this research method as a “process for identifying and critically appraising relevant research, as well as collecting and analysing data from said research.” The methodology aims to identify empirical evidence that fits the pre-

specified inclusion criteria to answer a particular research question or hypothesis. When conducting this type of review, it is possible to determine whether an effect is constant across studies, to discover what future studies are required to demonstrate the effect, and to discover which study level or sample characteristics affect the phenomenon being studied, like the cultural context.

The secondary data collection adopted for this study followed the systematic literature review process. This methodology aims to identify empirical evidence that fits the pre-specified inclusion criteria to answer a research question or hypothesis that aligns with this study's line of thought and research design. This section has explored the steps for one aspect of the study, specifically assessing the relationship between BD technology and the construction industry. The systematic review of the other aspects, such as the essential elements for adoption and the short and long-term benefits, was done simultaneously following similar steps.

Steps in the systematic literature review

In the study titled "Literature review as a research methodology: An overview and guidelines," Snyder (2019) suggested a four-phase design for conducting a literature review: (1) designing the review, (2) conducting the review, (3) analysis and (4) writing up the review. This process was selected to conduct the systematic literature review to explore the knowledge of BD technology, its relationship and its adoption in construction and its benefits.

- **Phase 1 - Designing the review:**

The process begins with a general scan of the literature to account for the existing literature reviews, to assess the number of research studies that must be assessed, and to help formulate and clearly define the purpose, scope, and specific research question that the review will address. The stated purpose should then guide the rest of the review. A search strategy for identifying relevant literature must be developed including selecting search terms and appropriate databases, as well as deciding on the inclusion and exclusion criteria, such as year of publication, the language of the article, the type of article, and journal.

- **Phase 2 – Conducting the review:**

A pilot test of the review process and protocol is appropriate when conducting a review. The process of selecting the sample can be done in several ways. For instance, this

can depend on the nature and scope of the specific review and how many articles are yielded.

- **Phase 3 – Analysis:**

After deciding on a final sample, a standardised means of extracting relevant information from each article must be established. Data abstracted can be descriptive information, such as authors, years published, topic, or type of study, or in the form of the effects and findings.

- **Phase 4 – Writing the review:**

Finally, for the writing stage, the final review should be structured. It needs to explain how the study was conducted, and its motivation should be clearly communicated. The literature review process needs to be transparent since it will allow the audience to properly assess the quality and trustworthiness of the findings.

This study performed an initial scan using the Science Direct and Google Scholar databases. From this initial search, 1,159 available sources were identified. A pilot was carried out with the results of the initial scan. The initial screening was performed by exploring the article's abstracts. From this pilot, it was established that most sources approached the subject speculatively about the possible impacts and benefits of BD in construction. No case studies on the technology were found. The criteria for selecting the sources are summarised in the following table (Table 4.5).

Table 4.5: Criteria for resource inclusion/exclusion

	Inclusion Criteria	**Exclusion Criteria**
Date	2008-2018	Prior to 2008
Language	English and Spanish	Papers written in a language other than English and Spanish.
Type	Original research paper, textbooks, technological articles and reports.	Book reviews, research notes and dissertations
Publication	Peer-reviewed articles, government reports, published textbooks, and conference proceedings.	Papers focusing on the technical areas
Design	Qualitative, quantitative, case studies, surveys, and studies that used a validated methodology	Informal papers with no research questions, no research process, and no defined data
Focus	Does the study explore the adoption of BD in the construction industry, its	Studies with no relationship to BD

	relationship, characteristics or benefits? Does the study identify the critical elements for BD adoption within the construction industry?	

Because of the lack of maturity in the field and the state of knowledge identified during the pilot, a primary literature review was performed, expanding the search scope. The online services of ProQuest, Scopus, and other external sources such as reports and articles from governmental and international organisations were included. The review process followed the same model as the pilot. It was conducted in stages by reading the abstracts first, making pre-selections, and then reading full-text articles before making the final selection. The process started with setting target dates according to the research program. The duration of each phase of the process is presented in Table (Table 4.6).

Table 4.6: Systematic literature review process

Phase	Process	Duration (weeks)
Review design	Development of the review protocol	4
	Pilot review of the literature	
	Protocol adjustment	
Conducting the review	Identification of the research	8
	Selection of studies	
Analysis of the sources	Study quality assessment	10
	Data extraction	
Writing the review	Data synthesis	5
	Keeping the review up to date	

4.5.2 Semi-structured Interviews

Semi-structured interviews were adopted as the data collection technique to answer the research question. Interviews are one of the main qualitative data collection methods. Depending on their structure, interviews can be classified as (1) structured, (2) semi-structured, or (3) unstructured (Barr et al., 2017).

- **Structured interviews:** This type of interview has a rigid nature and is composed of predetermined questions which is reflected in the type of response it collects with minimal variation allowed. One of the advantages of this method

is that it requires a minimal administrative effort and does not take much time to be carried out.

- **Unstructured interviews:** This type of interview is the opposite of the last category since it is composed of open-ended questions and has no predefined structure. Unstructured interviews allow the participant to lead the interview and require the researcher to process and analyse information in real-time to ensure that the relevant data is being collected.
- **Semi-structured interviews** can be considered an intermediate category since they have some of the characteristics of the previous methods. This type of interview has some structure without limiting the participant's freedom to explore other topics in more or less detail, encouraging a two way-communication with the researcher.

Semi-structured interviews, which are a reliable source of comparable data and let the participants freely share their points of view (Cohen & Crabtree, 2006), were selected as the data collection method. The semi-structured interviews were conducted to explore different areas concerning Big Data in the DR Construction industry. The steps taken in order to collect the qualitative data are explored within this section.

Sampling Criteria

During the SLR, two factors were established and served to shape the type of sample selected for the data collection. This discovery determined that the method for sample collection is non-probabilistic, characterised by using some of the criteria to select the sample (McCombes, 2021). First, the literature showed that the size of the company influences its ability to invest in new technologies where the bigger the company, the most likely it is able to possess the investment capability and accumulate the amount of data necessary to implement a successful BD analysis (Ngo et al., 2020). Moreover, it was also established that the people involved in a company's decision-making process influence adoption. Decision-makers not only have a deep knowledge of elements such as the drivers, benefits and challenges that can enable the adoption of new technologies, but they are also in the position to lead their organisations towards adopting the technology (Ngo et al., 2020; Maroufkhani et al., 2020). This factor determined the sampling technique as non-probabilistic, providing a group of characteristics that both the companies and participants should meet to be considered

suitable for this study. The size of the company and the position/experience of the interviewee were the factors considered when establishing the sample. The national taxpayer registry of the Dominican Republic was used to identify the construction companies with the potential to participate in this research.

The company size factors narrowed the sample to large and medium companies. Meanwhile, for the position within the company of the representatives, the selected characteristic was that the interviewees should possess a position that allows them to make decisions about the company's future and experience implementing new technologies or technological tools.

To identify the companies to whom the invitation to participate in the study would be directed, the official method of company classification of the Dominican Republic was engaged, which is found in the “General Law of Commercial Companies and Individual Limited Liability Companies” (Congreso Nacional de la Republica Dominicana, 2008). This system classifies the companies, according to their size and other characteristics, into four lines as presented in the following figure (Figure 4.5).

Micro
•Between 1–15 employees. •Less than RD$3,000,000.00 in active capital. •Less than RD$6,000,000.00 in annual revenue.
Small
•Between16–60 employees. •Between RD$3,000,000.01 – 12,000,000.00 in active capital. •Between RD$6,000,000.01 – 40,000,000.00 in annual revenue.
Medium
•Between 61–200 employees. •Between RD$12,000,000.01 –40,000,000.00 in active capital. •Between RD$40,000,000.01 – 150,000,000.00 in annual revenue.
Large
•More than 200 employees. •More than RD$40,000,000.00 in active capital. •More than RD$150,000,000.00 in annual revenue.

Figure 4.4: Company classification in the Dominican Republic
Source: Law 488-08 (National Congress of the Dominican Republic, 2008).

In the same way, the participants were selected according to their position within the participating company. A request was made for candidates within the managerial level of the company who took part in the decision-making process and, as far as possible,

those who were involved in developing new technologies within the company. Their demographic information is presented in the following table (Table 4.7).

Table 4.7: Demographic information for interviewees of the Dominican Republic

Code	Profession	Position	Experience (years)	Company Size
I-01	Civil Engineer	BIM Coordinator	7	Medium
I-02	Architect	BIM Manager	9	Medium
I-03	Civil Engineer	Project Manager	7	Large
I-04	Architect	Construction Superintendent	15	Large
I-05	Civil Engineer	Senior Planning and Control Engineer	19	Medium
I-06	Civil Engineer	Engineering and Projects Coordinator	7	Medium
I-07	Civil Engineer	Logistics and Material Supply Manager	7	Medium
I-08	Civil Engineer	Chief Executive Officer (CEO)	35	Large
I-09	Civil Engineer	BIM Construction and Management Manager	9	Large
I-10	Civil Engineer	Senior Project Planning Engineer	12	Large
I-11	Civil Engineer	Senior Project Cost Controller	7	Large
I-12	Civil Engineer	Project Quality Manager	5	Medium
I-13	Architect	Senior Project Designer	15	Medium
I-14	Civil Engineer	Vice-President of Operations	10	Large
I-15	Civil Engineer	Senior Project Manager	24	Large
I-16	Civil Engineer	Planification and Control Manager	15	Medium
I-17	Civil Engineer	Senior Project Manager	17	Large
I-18	Civil Engineer	Project Superintendent	17	Medium
I-19	Civil Engineer	Senior Project Manager	11	Medium
I-20	Civil Engineer	Engineering and Projects Coordinator	14	Medium
I-21	Civil Engineer	Senior Project Manager	22	Medium

Data collection

The purpose of this study was to gather information regarding the research questions established in this study. This stage of the project surveyed the Dominican Republic's construction industry regarding the concept of BD, its relationship with the industry, characteristics, and implementation.

The data collection process lasted from October 2019 to March 2020 and was held in Santo Domingo, Dominican Republic. The interviews were captured using voice recordings, and the duration was between nine (9) and twenty-two (22) minutes approximately. Each interview was transcribed and then translated into English from Spanish, the official language of the Dominican Republic, except one was in the English language with the prior approval of the interviewee.

A total of seventy-eight (78) companies were contacted and asked whether they would be willing to participate in the investigation. A primary response rate of forty-eight-point seven percent (48.7%) was obtained. The results represent the pre-interview process which can be divided into four stages from the moment of the first contact to the interview (Table 4.8). Stage I represents the total number of contacted companies from which thirty-eight (38) answers were received. Stage II represents the type of answer received about their willingness to participate; nineteen (19) companies responded with a definite willingness to participate, fifteen (15) responded with non-definitive interest, and the remaining four (4) companies expressed no willingness to participate in the study. Stage III represents the companies to whom all the information related to the study was sent and where another confirmation was requested to schedule the interview appointment. Twenty-six (26) companies responded with an affirmative answer, one (1) with maybe, and the other seven (7) decided not to participate. Finally, Stage IV represents the scheduled interviews of which twenty-one (21) were conducted.

Table 4.8: Pre-Interviewing Process, Willingness to Participate

Stage I	**78**	**Companies Contacted**
	38	Answered
	40	Not answered
Stage II	**38**	**Answered**
	19	Interested
	15	Maybe interested
	4	Not interested
Stage III	**34**	**Answered**
	26	Yes, going to participate
	1	Maybe going to Participate
	7	No, not going to participate
Stage IV	**27**	**Answered**
	19	Did Participate
	8	Not Participate

The saturation phenomenon was employed to determine the number of interviews that would be used for the investigation. Saturation is a well-established method to determine how many interviews are enough in a qualitative study. This term is used to identify the phenomenon where the interviews do not contribute any new or additional information to the investigation (Latham, 2020). In their study, Guest et al. (2006) reached the saturation point in the twelfth interview. This study's final sample consisted of twenty-one (21) interviews from 19 companies. Crouch and McKenzie (2006) stated that less than 20 participants in qualitative research help to establish a close relationship and, consequently, a more reliable exchange of information, identifying the ideal number as between fifteen and twenty (15-20) participants.

Another aspect considered is data generalisation from which conclusions can be drawn from particular situations (Polit & Beck, 2010). The economic growth of the Dominican Republic within the Latin America and Caribbean region is in an advantageous position. This could serve as an example of implementing new technologies such as BD.

Ethical considerations

This study relied on participant interviews as the primary data collection technique. This human interaction between the participants and the researcher had the possibility of posing ethical challenges. To avoid this, the ethical guidelines set by the University of Wolverhampton were followed in all stages of the data collection. An ethics form was submitted to the University of Wolverhampton, specifically the Faculty of Science and Engineering Ethical Committee, for approval before the start of the data collection process.

The researcher provided a participant information sheet and consent form, both available in Appendix C. It also explained how the data collected would be treated and what would happen to it at the end of the research. Anonymity was also assured for the participants and their organisations.

4.5.3 Data analysis

The steps that followed to analyse the collected data are explored within this section. There are different methods available for analysing qualitative data. According to

Hotjar (2022), the main techniques for this purpose are presented in the table below (Table 4.9).

Table 4.9: Main methodologies for qualitative data analysis.

Analysis Methodology	Definition	Advantages	Disadvantages
Content analysis	Content analysis is a research method that examines and quantifies the presence of certain words, subjects, and concepts in text, image, video, or audio messages. The method transforms qualitative input into quantitative data to help you make reliable conclusions about what customers think.	No need for direct interaction with participants to collect data.	Time-consuming when conducted manually.
		Easily replicable process once standardised.	The results are usually affected by subjective interpretation.
		Process can be performed automatically or manually.	Manual content analysis can be subject to human error.
		Does not require high investments or sophisticated solutions.	The process isn't effective for complex textual analysis.
Thematic analysis	Thematic analysis helps to identify, analyse, and interpret patterns in qualitative data.	One of the most accessible analysis forms.	-In a complex narrative, thematic analysis can't capture the true meaning of a text.
		Teams can easily draw important information from raw data.	Thematic analysis doesn't consider the context of the data being analysed.
		Effective way to process large amounts of data into digestible summaries.	Similar to content analysis, the method is subjective and might drive results that don't necessarily align with reality.
Narrative analysis	Narrative analysis is a method used to interpret the research participants' stories things like testimonials, case studies, interviews, and other text or visual data.	The method provides a deep understanding of participants actions and the motivations behind them.	Narrative analysis cannot be automated.
		Allows to personalise experiences.	Cannot be used with heavily structured formats.
		It keeps participants profiles as wholes, instead of fragmenting them into components that can be interpreted differently.	It requires a lot of time and manual effort to make conclusions on an individual participant's story. It's not scalable.

Grounded theory analysis	Grounded theory analysis is a method of conducting qualitative research to develop theories by examining real-world data. The technique involves the creation of hypotheses and theories through the collection and evaluation of qualitative data. Unlike other qualitative data analysis methods, this technique develops theories from the data, not the other way round.	It explains events that can't be explained by existing theories.	The process requires a lot of objectivity, creativity and critical thinking from the researchers.
		The findings are tightly connected to the data.	Because theories are developed based on data instead of the other way around, it's considered to be overly theoretical and may not provide concise answers to qualitative research questions.
		The results are data informed, and therefore represent the proven state of things It's a useful method for researchers that know very little information on the topic.	
Discourse analysis	Discourse analysis is the act of researching the underlying meaning of qualitative data. It involves the observation of texts, audio, and videos to study the relationships between the information and its context. The method focuses on the contextual meaning of language and sheds a light on what the audiences think of a topic, and why they feel the way they do about it.	It uncovers the motivation behind your customers' or employees' words, written or spoken.	Similar to most qualitative data analysis methods, discourse analysis is subjective.
		It helps teams discover the meaning of customer data, competitors' strategies, and employee feedback.	The process is time-consuming and labour-intensive It's very broad in its approach.

Source: Adapted from Hotjar (2022).

In this study, content and thematic analyses were used to analyse the interviews which generated themes that were explored more in-depth using situational awareness. According to Humble and Mozelius (2022), the two primary methodologies selected for this study are often considered similar since they have a similar process for coding data. The following figure highlights the main characteristics of each method.

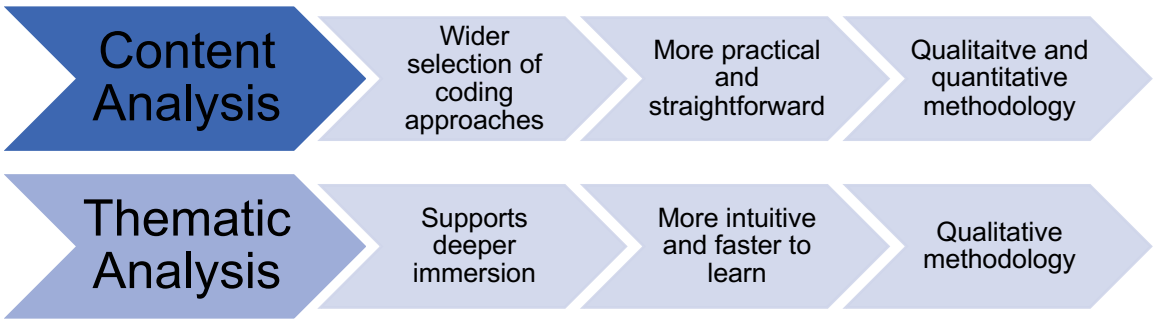


Figure 4.5: Comparison between the content and thematic analysis methods

Data Preparation

Part of a process described by Creswell in its "Guide for Qualitative Data Analysis" was considered in preparation for the data analysis (Figure 4.6). Creswell (2013) describes the five steps to prepare the interviews for the analysis process. The first three (3) steps were applied to the data collected as preparation for the analysis.

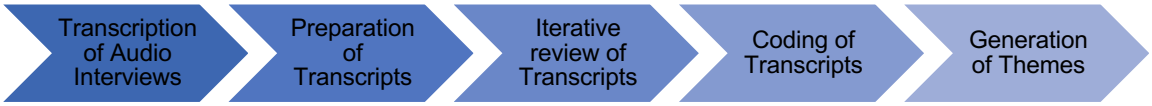


Figure 4.6: Creswell's Data Analysis Process described in "Guide for Qualitative Data Analysis"

The data analysis process of coding and generating themes for content analysis was performed using Microsoft Excel for the initial analysis and subsequent awareness measurement. During this process, each code was classified according to the level of knowledge demonstrated. This classification represented the levels of awareness about Big Data within the Endsley model.

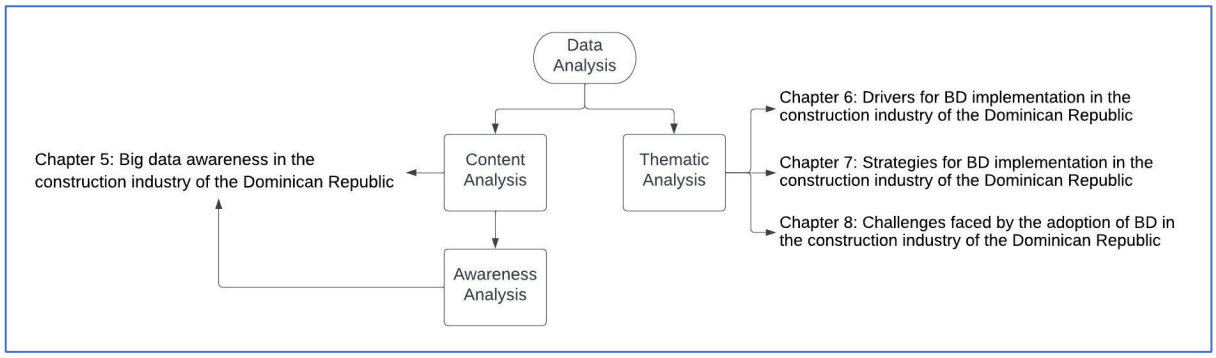


Figure 4.7: Methodologies applied in the data analysis

Additionally, the data analysis process of coding and generating themes for thematic analysis was performed using different versions of the program NVivo (11,12, and Pro). In this case, this software was used due to the large volume of data to be analysed. The first data preparation process presented was the same for both analyses. The following figure (Figure 4.7) shows where content and thematic analysis were used in this study.

Content Analysis

Content analysis was adopted as the analysis strategy to explore the status of BD in the Dominican Republic's construction industry, thus addressing the RO2 "To explore the understanding of the Big Data concept and its characteristics in the Construction Industry." According to Harwood and Garry (2013), content analysis can be defined as "a method for analysing the content of a variety of data, such as visual and verbal data." It supports the transformation of phenomena or events into defined categories

to assist in the analysis and interpretation. This methodology can be both qualitative and quantitative when applied in the developmental stages of research or to determine the frequency of a given phenomenon.

This study chose to select this methodology to answer RQ2: "What is the understanding of the construction industry about the Big Data concept, its relationship with the construction industry, and its characteristics?" since the data analysed through content analysis can be used to identify the frequencies of data which, in combination with the awareness analysis, increases the visualisation of the status of the technology in the context as mentioned earlier.

Situational Awareness Analysis

To "measure" the awareness of BD in DR, Endsley's "Theory of Situation Awareness" was adopted for this study. This, because it is the most generally accepted interpretation of situation awareness, is defined as the "… perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1995). Based on this model, the Situation Awareness Global Assessment technique, according to Dishman et al. (2020), is considered to be "the only direct and objective situation awareness measurement tool." Situational awareness in Endsley's model has

three (3) levels (Figure 4.8): perception, comprehension, and projection (Endsley, 2014).

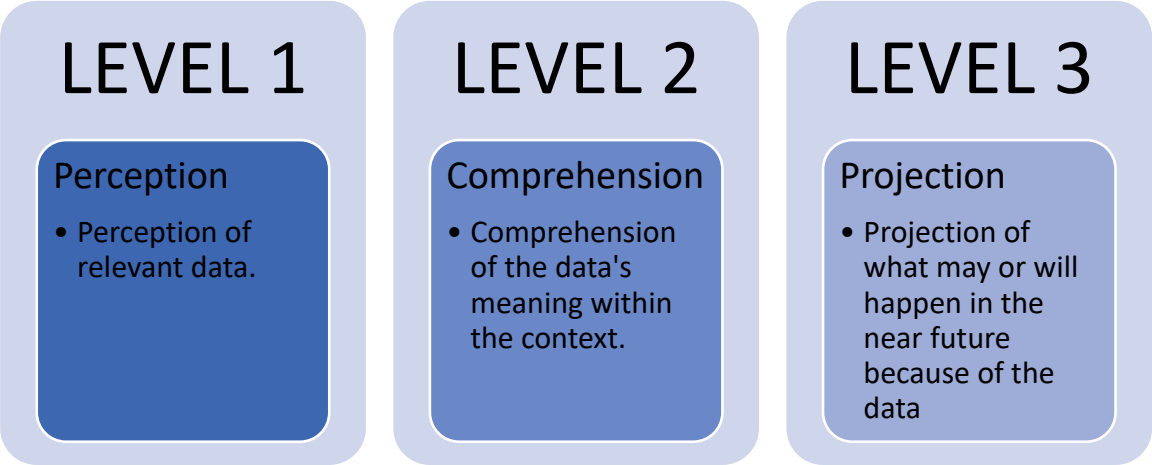


Figure 4.8: Endsley's original model of Situation Awareness
Source: Endsley (1995).

The concept of Situation awareness (SA) was initially used in military and aviation applications (Endsley, 1995). Over the years, the application of the SA can be seen across several industries to provide an awareness classification. For instance, disciplines such as health have used Endsley's model of SA in mental health (Moura et al., 2020), such as for thoracic surgery, obstetrics, nursing and anaesthesia (Dishman et al., 2020). Likewise, the program evaluation field used SA to help improve the decision-making skills of program evaluators (Marson, 2020). Manufacturing has also used SA analysis to reduce the incidence of accidents related to forklift driving (Choi et al., 2020). However, there is no evidence that this model has been applied to Big Data, particularly in the construction industry.

For this study, an adaptation of the Endsley Model was created (Figure 4.9). Level zero (0) of “No Awareness” was added.

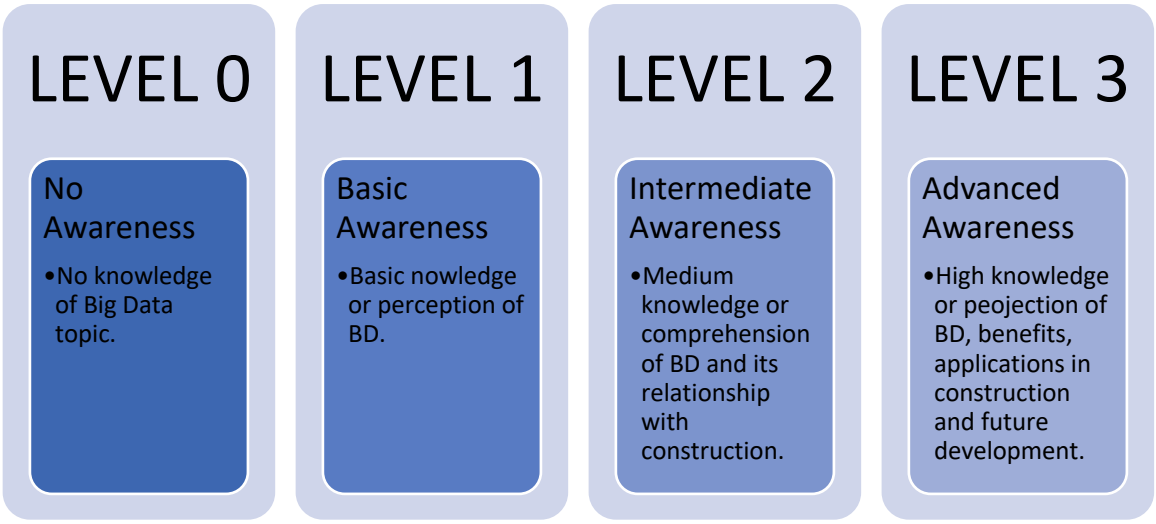


Figure 4.9: Endsley's Model Adaptation

Thematic Analysis

Thematic analysis is a method of qualitative analysis aimed at identifying the themes and patterns within the collected data sets. In this analysis, the researcher identifies themes within the gathered data regarding the research questions (Braun & Clarke, 2006). It differs from content analysis in that, in this case, the analysis is purely qualitative, while content analysis allows quantitative properties to be identified within the qualitative data. According to Joffe (2012), this method incorporates the core constellations presented in the data.

Thematic analysis was adopted for this study because it offers a straightforward, systematic, flexible and accessible approach to analysing qualitative data. According to Saunders et al. (2015), it represents an orderly, logical and exclusive way to analyse qualitative, ensuring rigorous and straightforward analysis. Moreover, this method is not tied to one research philosophy which aligns with the pragmatic ideology adopted in this study and provides an organic and reflective process (Neuendorf, 2018).

4.6 Development of the Big Data Readiness Assessment Tool and Framework for Big Data Adoption

The BD readiness assessment tool was developed from the combination of the study's findings and elements of the literature as a way of enabling organisations to better understand the BD adoption process.

The tool was developed to facilitate the readiness assessment of organisations within the Dominican Republic's construction sector when adopting BD. The readiness tool (available in Chapter 9) has been formulated as a survey that explores the three primary contexts of the organisations: technology requirements, organisation preparedness, and reaction to environmental pressure. The resulting score determines whether an organisation is ready or not to adopt the technology and on which aspects they need to work to ensure the successful implementation of sustainability strategies.

Similar to the BD readiness assessment tool, the strategic framework for BD adoption within the construction industry of the Dominican Republic was developed from a combination of primary and secondary data analysis.

The framework was developed as a response to the participants highlighting, during the interviews, that there is a need for a strategic framework for adopting BD within the construction industry of the Dominican Republic. During the primary data collection, the participants recognised that a framework for adoption would improve the chances of adopting the technology in the industry. The framework (available in Chapter 10) was developed to assist decision-makers and help them properly understand, manage and implement BD technology in the construction industry.

4.7 Validation of the BD Readiness Tool and Framework for BD Adoption

According to Leung (2015), in a qualitative study, validity represents the suitability of the tools, procedures, and data, and whether the outcomes of each stage are valid. The validation process for the readiness tool and framework took place in two stages.

First a hybrid workshop which started with a presentation of the research results to provide context and then an exposition and explanation of both the readiness tool and the framework. The participants then, provided their independent feedback in a series of one-to-one interviews which were carried out both face to face and online. The validation process started with purposive sampling which according to (Nikolopoulou, 2022) is a non-probabilistic technique where the sample is selected based on desired characteristics, in this case, the participant knowledge of Big Data and its previous

experience developing readiness tools. Due to the low response obtained with this technique, the snowball technique was also implemented. This method allowed the already "recruited" participants to recommend other people who they believe would fit the criteria for the study.

A total number of 17 people from five different countries, were contacted to participate in the validation process, of which, seven responded positively and participated in the validation process. Participants are from the Dominican Republic (DR), United Kingdom (UK), United States of America (USA) and Canada (CA). The following table (Table 4.10) presents the demographic information of the participants selected for the evaluation process.

Table 4.10: Demographic information for evaluation process

Code	Profession	Position	Experience (years)	Country	Company Size
I-01	Civil Engineer	BIM Coordinator	7	DR	Medium
I-02	Architect	BIM Manager	9	UK	Medium
I-03	Data Scientist	Data analyst	4	USA	Large
I-04	Big Data Architect	Data Manager	3	USA	Medium
I-05	Architect	BIM Designer	13	CA	Large
I-06	Lecturer in Data Science	Lecturer in Data Science	8	UK	Large
I-07	Big Data Engineer	Chief Data Officer	6	UK	Medium

As mentioned before, the participants were presented with both outputs (Readiness Tool and Framework) and were given between four and ten days to review and provide their feedback. A total of five questions were developed to assess the tool's level of understanding, level of termination, logic flow, usefulness and a final question allowing for any comments from the participants regarding necessary improvements.

The evaluation process for the research outputs is available in the link below. It contains the questionnaire presented to participants. The questions were specifically designed to understand the interviewee's point of view about the framework and allow its review.

Questionnaire link: https://forms.gle/qmaMWAWbBUnakNdp9

4.8 Reliability and Validity of Research

Reliability and validity are concepts used to assess the quality of research. They reveal how well a method, technique, or test measure something. Reliability is about consistency, and validity is about the accuracy of a measure (Middleton, 2022). In any case, the reliability and validity of the research results depend on creating a robust research design, choosing appropriate methods and samples, and conducting the research carefully and consistently.

To ensure that the results were both reliable and valid, the decision-making process for conducting this study followed the logical flow of qualitative research, as described earlier in this chapter. Each decision addressed the research problem and was based on specific criteria.

4.9 Summary

This chapter provided a detailed explanation of the research methodology and procedures utilised while gathering and analysing the required data to answer the research questions stated by this investigation. Various research methods were used, such as a critical review of the literature, semi-structured interviews, and thematic and content analysis. Behind these methods, there was a pragmatic research philosophy which allowed the researcher to be flexible about the methods and techniques used for data collection depending on the nature of this research.

The semi-structured interviews gathered empirical evidence explaining the drivers, strategies, challenges, and critical success factors for adopting BD in the construction industry. This information was used to build and validate an organisational readiness assessment tool for adopting BD and a strategic framework for BD adoption within the industry.

The following chapter commences the discussion of the research findings by discussing the status of BD awareness in the Dominican Republic's Construction Industry. Chapters 5 to 9 present the remaining findings of this investigation.

CHAPTER 5. BIG DATA AWARENESS IN THE CONSTRUCTION INDUSTRY OF THE DOMINICAN REPUBLIC

5.1 Introduction

This chapter addresses Research Objective Number Two (RO2): "To explore the understanding of the Big Data Concept and its characteristics in the DR Construction Industry", by providing an answer to RQ2: What is the understanding of the construction industry about Big Data Concept, its relationship with the construction industry and its characteristics? The chapter discusses the level of awareness or understanding of BD concept and characteristics in the construction industry of the Dominican Republic. The process through which an organisation assumes a new technology as part of its structure in order to improve the delivery of its products or services is known as adoption (Silverio-Fernandez, 2019) and this is the consideration that has been investigated in this study. This chapter addresses the current situation of Big Data in the construction Industry by analysing its awareness which, according to the Cambridge Dictionary (2020), is "knowledge that something exists or understanding of a situation or subject at the present time based on information or experience."

The findings presented in this chapter were developed from the systematic review of the relevant literature and the analysis of semi-structured interviews. Twenty-one (21) professionals from 19 medium and large companies from the Dominican Republic Construction Industry were interviewed.

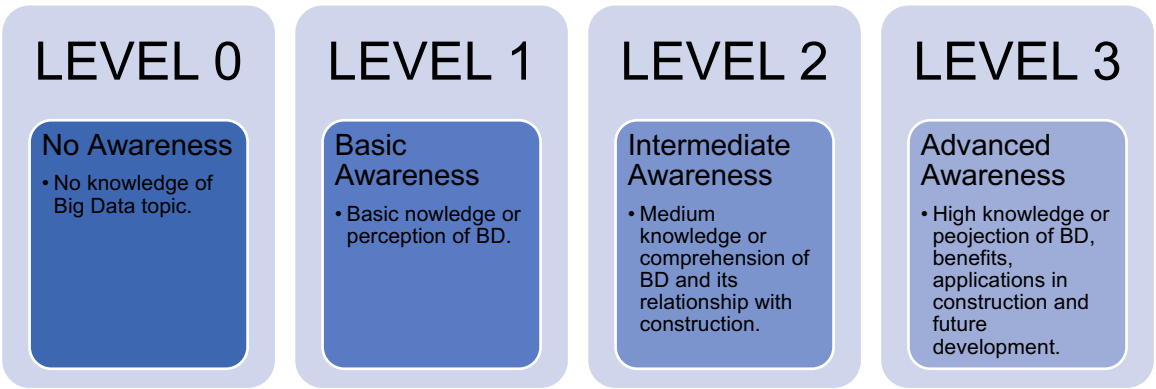


Figure 5.1: Awareness Model Adopted by the Study.

The analysis of the literature revealed a lack of sources that discuss the adoption of technology in the construction industry and where it is still considered to be emerging (Susanto et al., 2019). The general results are represented in the Table below (5.1) where in all cases the largest number of responses were classified at the basic level.

Table 5.1: Overall answer classification within the modified Endsley's model

	Level 0	Level 1	Level 2	Level 3
What is your level of awareness of the "Big Data" concept and its relationship with the construction industry?	33%	33%	29%	5%
Are you aware of the volume of data produced in a construction project and the variety of that data?	10%	52%	38%	0%
Are you aware of the volume of data produced in a construction project and the variety of that data?	43%	43%	10%	5%
Are you aware of the benefits as a result of BD adoptions in other industries?	10%	67%	19%	5%

This chapter is structured as follows: Section 5.2 presents the findings regarding levels of concept awareness and the awareness of the relationship between BD and the construction industry. Section 5.3 shows the awareness around BD characteristics. Section 5.4 discusses the awareness of any existing data management protocol in the organisation and how this translates to BD adoption. Section 5.5 reviews the awareness of BD implementation outside the construction industry. Section 5.6 discusses the relevance of these findings and finally, Section 5.7 summarises the findings of this chapter.

5.2 Concept Awareness and Relationship with Construction

The data captured in the interviews was subsequently processed by analysing the content and subsequently application of a modified version of Endsley's of Situation Awareness Model (Figure 5.1).

To capture the level of awareness on the concept of "Big Data", the first question was raised, i.e., what is your level of awareness of the "Big Data" concept and its relationship with the construction industry? Overall, the interviewee's awareness of the BD concept was distributed between various levels of situational awareness in the

modified Endsley's model. Of the interviewees, 33% (7 of the 21) noted that they had "no awareness" or had never heard of the BD concept and its relationship with the construction industry. This is reflected in the no awareness Level 0 of Endsley's model. For instance, Interviewee I_8 highlighted that:

> *"No, I had not really heard the term until this moment". I8*

It is evident from the above statement that the DR construction organisations lack a basic understanding of the concept of BD which agrees with the literature in the classification of BD as an emerging technology for the construction sector (Bilal et al., 2016; Garyaev & Garyaeva, 2019). To improve the DR construction industry's competitiveness, the decision makers have to recognise and understand the concept of BD. It is worthwhile to consider a holistic impact of BD concepts to improve the project delivery processes of the DR construction industry.

Of the interviewees, 33% (7 of the 21) had a "basic awareness" of the concept of BD at Level 1. This is reflected in the basic awareness Level 1 of Endsley's model. For instance, Interviewee I_{20} highlighted that:

> "Very generally, a big database that can be used to identify trends and to manage information". I20

Similarly, I_{12} stated that:

> *"I've heard of the term applies to statistics and economy, but I never hear of any relationship of BD and Construction". I12*

From the above, it is evident that there is a basic awareness of what BD is but not concerning the construction industry. This is consistent with the fact that BD has presented great developments in more technologically driven industries and, on the contrary, is barely making itself known in the construction industry (Caesarius & Hohenthal, 2018; RICS, 2020; Silverio-Fernandez et al., 2019). Therefore, there is a need to raise the awareness of BD concepts and applications in the context of the construction industry.

Of the interviewees, 29% (6 of the 21) noted that they have an "intermediate awareness" of the concept of BD. This reflects on the intermediate awareness Level 2 of Endsley's model. For example, I_4 and I_{11} noted that:

> *"BD in relation with the construction industry is about the amount of data created in a construction project". I4*

"From what I understand is that this technology allows you to extract insights of data from past projects in order to make better decisions in the management of the future projects". I11

From the previous statement, it is evident that there is an intermediate level of awareness in terms of the applications of BD in the construction industry but the interviewees were not involved in the implementation of the BD concept. This can be considered a reflection of the industry's inherent resistance to change (Ngo et al., 2020).Therefore, it is important to document and provide BD leadership awareness programmes that include a holistic approach for implementing BD in the construction industry.

However, only 5% (1 of the 21) interviewees noted that they have an "advanced awareness." This reflects on the advanced awareness Level 3 of Endsley's model. Interviewee I_1 noted that:

"I knew the term Big Data, actually last year because I used a software for data analytics as it is a big corporation, they have like two departments, one for construction and one that's like a supplier. The operation manager used information for the statistics of the sales which quarter of the year make the most, in comparisons with this year and the last year. As well as the construction department saw how they used the information. As a big corporation, more data is gathered on a continuous basis. Therefore, I had to learn what Big Data is and how to manage Big Data and apply it to provide trend analysis and enhance decision making". I5

Overall, there is a basic level of awareness around the concept of BD which agrees with much of the literature indicating that in recent years, there has been an exponential increase in the use of both the term and technology (Wang et al., 2020). It is evident that 66% of the interviewees (14 of the 21) lack a basic understanding of the concept of BD and its relevance to the construction industry. Implementation efforts would benefit from training programs focused on digital skills since there is a need to develop a continuous professional development programme for the benefit of present construction professionals in the DR.

5.3 Big Data Characteristics

The second question explored the level of awareness around the BD defining characteristics, i.e. Are you aware of the volume of data produced in a Construction Project and the variety of that data? In this case, more than half of participants showed evidence of belonging to the basic level of awareness within Endsley's model, whereas the rest was distributed between medium and no awareness with the highest percentage belonging to medium awareness.

Of the interviewees, 5% (1 of the 21) had no awareness or knowledge of the BD characteristics asked in question two which places them within the No Awareness level (Level 0) of the model, as evidenced by the following comment from I_{16}:

> *"Well, we always try to have everything in physical form in each project, in the office we keep copies and files of everything but in site, we have everything printed, you know if someone needs to check something or you have supervision visiting, everything needs to be there. Well, we storage basically everything, from CAD blueprints to pdfs, to the payroll of the workers, etcetera". I6*

The above shows that there is an existing part of the industry in the DR that is not yet integrated into project digitalisation. The industry is still dependent on printed material to manage projects on-site (Agarwal et al, 2016), demonstrating a clear need for understanding benefits such as transparency and the reduction of errors that happen as a result of the digitised management of the projects, which technologies such as BD can provide.

Nevertheless, 57% (12 of the 21) of participants demonstrated a basic awareness of the BD characteristics when questioned. For example, I_{15} and I_{19} agreed that:

> *"Well, I couldn't give you a specific number, but only between the different versions of the same documents, I mean, every time that we have to modify a blueprint lest say, we store all the previous versions, and that could take Gigabytes a single document, I don't know if you understand what I mean, and the variety has to do with all the different formats". I15*

> *"I would say that I have an idea of how much is produced in a project, you mentioned things like, spreadsheets, blueprints, pictures, maps, etcetera". I19*

These comments reveal that most professionals in the construction industry possess, to some extent, an understanding of the characteristics of BD in terms of volume and the variety of data handled in a construction project, thus demonstrating basic awareness. In the same way, it is evident that there is a need to further popularise the concept and its characteristics to create a general uniform understanding of the technology and how to benefit from it.

Finally, 38% (8 of the 21) participants showed a medium awareness of the BD characteristics, demonstrating a deeper understanding of the implications of the data generated in a construction project and how it relates to BD and the "Intermediate Level of Awareness" level in Endsley's Model. For instance, Interviewee I_2 noted that:

> *"Eh, like tangibly no, but I do know because I work with that, I work data production, information production and transmission, now, I know that there is a background, like something that you cannot see, some invisible information that is also part of it that I don't really know to which magnitude it develops or grows on the back". I2*

These comments demonstrate an intermediate level of awareness and understanding of the characteristics within the sample, and that overall, the participants have a good idea of the data produced in a construction project and how this data fits in the BD technology. However, it also illustrates the need to provide the necessary tools and training needed to drive adoption.

In the case of BD characteristics, no interviewee expressed advanced awareness or a high understanding of what they are and how they can be identified within the construction industry context, reaffirming the need for professional training focused on the following of future industry developments. This will mean that when they encounter the elements that currently serve as the basis for these technologies, they will know how to identify them and take advantage of their potential.

5.4 Data Management Protocols

After asking the participants about the volume and type of data that they handle in their construction companies, another question was asked to explore whether their organisations have any protocol of data management in place. Their answers were distributed within Endsley's Model of SA in the following way:

Of the interviewees, 43% (9 of the 21) expressed not having any data management mechanism in place in their respective companies, which places them within level 0 of "No Awareness" in Endsley's model. The answers provided by Interviewees I_{15}, I_{19} and I_{21} exemplify the two situations that were found in this case:

> *"Ahh well, we store it, while the project is running it stays in an open online server that way everyone involved can have access to it and then when the project is finished, we back it up and store it in the cloud. Yes, we found that this is the best way to ensure that everyone can contribute and once you finish, either for an audit or just to keep as company records you need to have all the final documents safely storage". I15*
>
> *"Only storage". I19 and "No, I don't think so". I21*

The first two comments (I_{15} and I_{19}) describe the situation in which the interviewees did not recognise data storage as a data management protocol. The action of storing digitised information either on the Cloud or on a physical server conforms to a data management process since data management is the process of collecting, organising, storing, and maintaining the data produced by an organisation (Stedman & Vaughan, 2019). The third comment (I_{21}) depicts the situation in which the organisation simply does not possess such protocol at all. In either case, the need to clarify the concept of BD and its implications is evident.

Another 43% of interviewees (9 of the 21) expressed having some kind of data management protocol which in most cases was an online database with the information of previous and current projects. This recognition of the protocol is what has placed them at level 1, the "Basic Awareness" of Endsley's model as evidenced by Interviewee I_{10} in the following comments:

> *"Yes, but not in a structured way. We have received or well-integrated application proposals such as Aconex and Procore but we still do not see it feasible. Meanwhile, we handle everything from a protocol of folders in Dropbox". I10*

In the same way, Interviewee I_{11} stated that:

> *"Yes, we use cloud storage, so all data is available at all times". I11*

The previous statements show that a pressing need exists for the Dominican industry to adopt and relate to digital terms that will help open the doors of modernisation, not only with the adoption of BD but also with the adoption of other predecessor technologies and simple protocols such as data gathering and data storage which in most cases is already being implemented without being identified as such.

Of the participants, 9% (2 of the 21) provided answers fitting to an intermediate awareness of data management protocol in their companies with data gathering or project management software in place. In this matter, I_1 comments that:

> *"Not, not actually, I mean, like I, like I said we used a software that already gathers the data, and we only worked with that data, but the pictures, the videos, or the, or the spreadsheets, people use in site, but we didn't do anything with it". I1*

The percentage of companies that recognise and use some type of data management system is minimal which the great need for understanding these tools and the benefits that they can provide to increase efficiency and productivity.

Ultimately, only one participant representing the last 5% had "Advanced Awareness" or a high comprehension of the issue of identification and the implementation of data management or analysis tools. Interviewee I_5 noted that:

> *"We use a management program: PMWeb; outstanding follow-up program: Asana. We also have protocols presented by the manager and owner of the company to maintain the organization of information between projects". I5*

With the exception that it is a traditional data analysis system, Interviewee I5 exemplifies a scenario where the company has identified the benefits of adopting a data management tool and has decided to invest in its development. Unfortunately, this case represents the minority of companies, but it could, in turn, serve as an example like a case study that could guide the industry in the near future. However, more cases like this are needed to generate confidence in this new technology.

Overall, there is a lack of basic awareness around the protocols and practices that conform BD, meaning that even when there is some level of understanding, the basic elements for data accumulation are either not known or not implemented within the construction companies or in some other cases known but not recognised as such by

the decision makers. This reaffirms the need for including the exploration of new technological developments within the industry.

5.5 Awareness of Implementation Outside the Construction Industry

The final question of the section explores the awareness of the participants of any other application of BD outside the construction industry, i.e. Are you aware of the benefits as a result of BD adoptions in other industries? This yielded mixed results that were distributed between the four levels of the modified Endsley's model. Most of the answers were mainly distributed between levels 0 and 1 with the remaining amount between levels 2 and 3 of the model.

Specifically, 38% of interviewees (8 of the 21) expressed having no awareness of any other general BD applications of BD outside the construction industry. This percentage is closely related to the 33% obtained for the same level in question number one, meaning that most of the people did not know the term or its relationship with the construction, nor had they have heard of it outside this scope. In this case, Interviewee I_4 expressed that:

> *"No. nothing that I could mention specifically".*

This statement can be considered an indication of the early stage of development of BD in the construction industry (Bilal et al., 2016; Garyaev & Garyaeva, 2019). Therefore, there is a need to raise awareness of the topic and its applications not only within the industry but in general with the hope of improving the understanding of the BD and creating momentum for its adoption.

Of the interviewees, another 33% (7 of the 21) expressed that they possess a basic awareness or perception of other BD applications outside the construction which allocates them to Level 1 in Endsley's model. In this case, most of the people had heard vaguely of the term in other fields rather than the construction industry. For example, I_{20} expressed that:

> *"Again, very vaguely I could say I've heard of its use in information management and in statistics to identify trends, I couldn't say more than that". I20*

The great part of the Dominican construction industry that has very little or no knowledge about this technology. This indicates a lack of interest in modernisation

and follow-up of new technologies. It also reveals the need to foster professionals who lead the industry by being bold, accepting risks and adopting new technologies similar to this one that today is being established or explored in almost all other industries.

Moreover, 19% of interviewees (4 of the 21) expressed an intermediate level of awareness of Endsley's model, detailing specific areas of implementation outside the industry. Very concisely, Interviewee I_{11} expressed that:

> *"In other countries, they have been able to predict shopping tendencies and even drops in the Stock market using BD". I11*

Similarly, Interviewee I_{17} also noted that:

> *"Well, Big Data per se no, but data analysis that I understand I kind of the same in a much smaller scale, yes, I've seen the things that you can do by analysing data, things like, create predictions and improve the decision-making process, I think that the benefits of BD would be something similar, right?". I17*

The above indicates that even when part of the industry recognises and understands the benefits or implementation of BD in other industry, the need still exists to expand the knowledge and strengthen the relationship with the construction industry by promoting the use of the technology and including these examples as part of the motivation for the implementation.

Ultimately, the remaining 10% (2 of the 21) of interviewees demonstrated an advanced level of awareness with very specific examples of implementation outside of construction. This places them at level 3 of Endsley's model. For instance, Interviewee I_{21} said that:

> *"Yes, according to what I learned it has been developed or used in areas such as health to predict outbreaks by analysing the behaviour of previous outbreaks. And to predict changes in retail, where they can predict what the clients will buy by also analysing their purchase behaviour and that way, they can send you personalised ads in your computer. But of course, it raises some questions about security and the management of the data that we allow some apps and companies to have about us". I21*

The low percentage of the industry that possesses this type of essential knowledge demonstrates the need to educate current and upcoming professionals in areas that could be projected as the future of the industry. Its inclusion in the educational

curriculum and professional training is evidenced by the lack of generalised knowledge and understanding that is demonstrated in each of the questions above. The industry needs to modernise, starting with the recognition of the practices that are being currently implemented that in the near future can help the adoption of new technologies such as BD.

The study shows that the depth of this knowledge is still very little, evidencing the need to further exploring not only the concept but all aspects of the technology including its application in other industries which could be translated in a better general understanding. This agrees with what was expressed by Vellante (2021) who indicates that early adopters face a basic lack of knowledge about BD's application in construction.

5.6 Discussion

The need to manage the increasing volume of data that is being produced today is a major key driver for many industries that have already been making inroads in the adoption of Big Data and data management technology for years (Tamiminia et al., 2020; You & Wu, 2019). This phenomenon undoubtedly also occurs within the construction industry. Plenty of literature exists reflecting on the positive results of adoption BD in other disciplines (Caesarius & Hohenthal, 2018; Pigni & Watson, 2016; Raguseo, 2018; Tamiminia et al., 2020; The Economist, 2012). Meanwhile, in the construction industry the studies exploring Big Data adoption are limited, indicating the presence of a gap. Still, areas such as project waste management, energy efficiency, project planning are already benefiting from BD implementation, driven by the use of technologies and trends such as BIM and Construction 4.0. This also contributes to the growth of BD datasets through the promotion of Cloud storage and the use of data generating equipment in construction (Berger, 2016; Burguer, 2019; Wood, 2018).

This section assessed the level of awareness that main characters of the industry possess on BD, counting on their central role for the future implementation of the technology. The results revealed the awareness of the industry representatives when it comes to BD concept and characteristics, showing that overall there is a basic level of awareness prevailing within this field, this means that an in-depth and focused homogenisation of the concept and its characteristics is required to ensure the industry-wide implementation of the technology.

Moreover, the results demonstrated that the concept of Big Data is generally known in the Dominican Republic's industry which agrees with much of the literature indicating that in recent years, there has been an exponential increase in the use of both the term and the technology (Wang et al., 2020). But at the same time, there is a lack of understanding about the possible connection between BD and construction, identifying this as the main challenge since most of the participants that did know about the technology were unaware of its applications in the industry. On the other hand, the literature shows that the basic elements for data accumulation and transmission in the form of Cloud storage and data-generating and transmitting devices are already widely used in the world industry with the Dominican Republic being no exception (Burguer, 2019; Wood, 2018). This is even when they haven't been recognised as such or put in place for BD purposes.

The accumulation of large volumes of data is an important driver for the implementation of BD in most industries (Boyd et al., 2020). For instance, according to Garyaev & Garyeva (2019), the industry-wide adoption of BIM, which contributes more than 100GB of data from each project, represents a great input to the creation of BD databases that can be used for analysis and the extraction of insights that can improve decision-making and the generation of necessary feedback processes. In contrast, the inherent resilience of the construction industry to implement new technologies that do not have a high and proven success factor plays against any move towards implementation (Ngo et al., 2020). This indicates that overcoming this is a primary thing to develop for the successful adoption of Big Data and any new technology.

The findings of this research will increase researchers and managers awareness, and at the same time, will allow them to understand that at this moment, the main barrier to the adoption of Big Data is the lack of concept generalisation as well as the lack of understanding about the tools necessary to manage the data. This could potentially help them to react accordingly in order to minimise the obstacles at the time of implementation. This study could also serve as a base of knowledge and a drive to reach a higher level of awareness of the technology and its benefits together with the understanding of what is being done and what is still needed to adopt BD as part of the construction industry culture of project deliverance. However, the low level of awareness demonstrated by many of the participants could also represent a limitation

for this study and affect its validity, since many of the insights provided were based on their experience with similar technologies and no BD.

5.7 Summary

This section represents an exploration of the awareness and knowledge of the BD concept and its characteristics. With this, a baseline has been determined from which the factors for a future implementation of the technology in the construction industry can be determined. The study was carried out by assessing the level of BD awareness of the industry's decision-makers on which a future BD implementation in construction will depend. To assess the level of awareness regarding the concept and characteristics of BD technology in the construction industry of the DR, this study applied the situational awareness model developed by Endsley in 1995. This model is considered since its development as the most generally accepted interpretation of situation awareness (Stanton et al., 2001).

In response to the query posed in RQ2 which in turn satisfies RO2, the results revealed the awareness state of the industry when it comes to BD, showing that overall, there is a basic level of awareness prevailing within this field. This is an indication of the need for concept and characteristic popularisation as a primary step for the implementation. This is also supported by the high level of ignorance around BD requirements or characteristics which is also reflected in the results. This denotes that the concept, requirements and more technical aspects of the technology should reach a higher level of understanding before the technology can be fully adopted.

The lack of in-depth and homogenous understanding appears to be an issue that came to light in each area explored by this research for which it could be considered the main problem. This is followed by the need for education and training aimed at present and future professionals to equip them with the tools that allow them to identify, take advantage of and implement technologies that will positively impact the industry in the future.

The next chapter (Chapter 6) will focus on the enquiry into drivers for the implementation of BD in the construction Industry.

CHAPTER 6. DRIVERS FOR BIG DATA IMPLEMENTATION IN THE CONSTRUCTION INDUSTRY OF THE DOMINICAN REPUBLIC

6.1 Introduction

This section presents the main factors that influence the adoption of new technologies such as Big Data in the construction industry as identified by the interviewees. This chapter satisfy research objective number three (RO3) “To investigate the drivers for implementing BD in the construction Industry” which, in turn, satisfies research question number 3 (RQ3) “What are the drivers that impulse the implementation of BD in the construction Industry?

Drivers are the inner or outer forces that shape transformation in an organisation (Spacey, 2018). This change can be to adopt new plans, designs, products or, as in this case, new technologies. The following figure (Figure 6.1) shows the key drivers identified in this study. The results presented in this section are the result of the analysis carried out on the data collected in the construction industry of the Dominican Republic. Thematic analysis was implemented to identify the drivers that influence the adoption of Big Data in this industry. The results presented below have been generally classified under one of two sections, internal and external, based on the origin of the drivers in relation to the company that the interviewees represent. Each section, i.e., internal drivers, has themes i.e., technology awareness, arising from the data analysis and representing the influencing factors for adopting the technology.

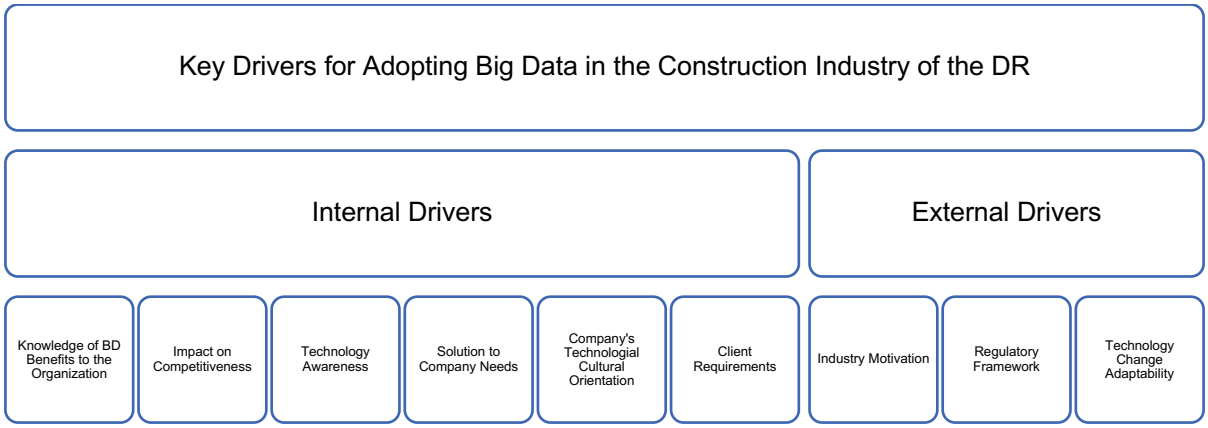


Figure 6.1: Key Drivers for Adopting Big Data in the Construction Industry of the DR Identified During the Data Analysis

This chapter is structured as follows: Section 6.2 discusses the internal drivers identifies in the data analysis, then Section 6.3 addresses the external drivers. The general discussion of these challenges is presented in Section 6.4 and in Section 6.5, there is a summary of the chapter.

6.2 Internal Drivers

The drivers discussed below represent the interviewees' opinions about the factors that, from within the organisation, influence the adoption of new technologies such as BD.

6.2.1 Knowledge of BD's benefits to the organisation

A determining element identified in the implementation of BD and new technologies in general is that decision-makers understand the benefits of the technology (Silverio-Fernandez et al., 2019). This could ease the adoption of the new technology so then there are realistic expectations about the results that can be obtained from it.

As an example of this, I14 explains in the comment below why they consider that knowledge of the benefits is a key driver of the implementation of BD in the construction industry:

> *"I believe that the key thing is that to let industry to know the benefits and the impact that Big Data could have in their organizations and their revenue, I think that most decision-makers in the companies tend to keep doing the same things that they know work for then rather than explore new things that they could apply to their practices. So, if they don't know what is or how they can benefit from it I doubt that any industry-wide implementation will occur". I14*

With this statement, I14 indicates that a strong motivation for organisations to implement a new technology like BD is to know what benefits or advantages such adoption would provide organisations and that this knowledge of the benefits would also help to overcome the resistance to change in the industry. Following this line, I18 expressed the following:

> *"Well, it should offer a clear benefit to the industry or companies that are willing to implement it...". I18*

Similarly, when asked about the key drivers of the implementation of technologies such as BD in his company, Interviewee I18 recognises that the knowledge of specific

benefits is a determining factor in the adoption of BD. Following this line, many sources in the literature agree with this aspect. Neilson et al. (2019), Li et al. (2019) and Maroufkhani et al. (2020) recognised the need to have specific knowledge of the results to be obtained that motivates them to create change in their institutions, a concept with which I2 agrees when it expresses the following:

> *"[…] I think that for us to implement something like that we should be able to identify the benefits, and how it would fit in this company or how we would use it, it should have some type of international backing, I mean that the international community recognises its value". I2*

The knowledge of the benefits based on the experience of other companies that have already adopted the technology is also considered to be an important aspect to promote implementation, as expressed by Interviewee I17 in the comment below. Moreover, the possibility of exploring results obtained by other companies through detailed case studies where the technology has been successfully implemented would create validation in the industry that would benefit the implementation of the technology. This would be even more so when this example comes from the same country or where similar conditions of the industry are found as indicated by Silverio-Fernandez et al. (2019).

> *"[…] well, I don't know, it could be anything from the popularisation of a company where it is been implemented and that shows positives results or it doesn't have to be a company if you come across a project where this type of technology was implemented and you find that that project has some advantages when compare to other similar projects that didn't have the technology then that would be a good precedent or motivator for the adoption in the industry and along with other companies with the same type of projects, or who knows, maybe some will adventure to apply it to many different projects to see if they end up with the same advantages". I17*

Conclusively, knowing the benefits that the organisation will obtain from the implementation of technologies such as BD is a determining factor in its adoption. The above statements denote that for a new technology such as BD to be implemented in the construction industry, it must provide attractive perks that decision-makers cannot resist such as a competitive advantage over their competitors or an increase in revenue. If there are practical examples that describe in detail the experience of other

companies under similar conditions when they have applied this technology and obtained benefits, even better.

6.2.2 Impact on competitiveness

Another leading factor identified was the impact that the adoption of this new technology could have on competitiveness or the ability to deliver better value over other companies that offer similar services. One respondent identified competitiveness as a need of his organisation, and he considered it to be a good decision when he adopted any technology that could improve the company practices. This agrees with what was indicated by Madanayake and Egbu (2019) about BD improving the competitive advantage by supporting data-driven decision-making.

> "I think that the need to be competitive and that anything that has the capacity of improving the processes that we do as a company is worth looking at". I16

Following the same line when asked about the key factors that could promote the adoption of new technologies such as BD in his organisation, Interviewee I7 also recognises the maintenance of competitiveness as a necessity and identifies the adoption of technologies such as BD as a response to satisfy this need, commenting that:

> "[…], basically, I believe it would be the necessity of maintaining international standards and competitiveness". I7

Undoubtedly, the recognition of the adoption of this technology as the solution to competitiveness, a condition that is considered a key aspect for organisations, can be considered a key driver for its implementation.

Moreover, profit is a defining factor for companies as an objective. It is what differentiates businesses from other "non-profit" organisations. In the same way, the expectation of an increase in profit can motivate or promote the adoption of new technologies such as BD (Raguseo, 2018). In this line, the participants agree that a determining element for the adoption of BD in the construction industry is the possibility of receiving an increase in profits for organisation, as evidenced by their comments below:

> *"[…] and I would also have to say profit, I mean this whole industry thrives because of the profit that it generates so a good incentive for the industry to*

implement a new practice or technology would be that said practice or technology produce an increment in their profit". I5

Also:

"Well, I believe we have a technology-driven culture in the company, also, the need for efficiency and transparency and the optimization of profit is what comes to my mind right now". I10

Undoubtedly, the promise of an increase in the profit of the companies is a key driver for the implementation of any technology, an aspect that BD certainly covers directly and indirectly by improving the decision-making process, improving resource management, reducing costs by improving waste management and energy consumption and so on.

6.2.3 Technology awareness

Technology awareness refers to the ability to comprehend and recognise the value that new technology can provide the business. It also involves keeping up to date with the evolution of technology (Silverio-Fernandez et al., 2019). The fact that this technology is considered new in the construction industry raises questions about not only the concept but also its characteristics, benefits, and what the steps are for its implementation. In this regard, Interviewee I16 commented:

"[…] I would say generalisation of the term, that more and more people come in contact with it and understand it, and also, that they learn how to apply it and how to benefit from it". I16

Also:

"Well, I think is basically that the people involved in the industry need to know the concept and how its adoption could benefit their companies, yeah, I think that is the most important thing". I15

The previous comments indicate that there must be real and deep knowledge about the technology for it to be adopted within the industry. Interviewee I2, commented on the fact that because of the way the world today works, the accumulation of digital data exists, and it is growing exponentially without interruption. Construction companies are not the exception.

"[…] to raise awareness of the existence of it and that we all generate BD in the world that we are developing, then, what benefits we can extract from it". I2

In summary, decision-makers need to understand how the technology works, how it can be implemented, what benefits they can expect from it and so on. These are the determining factors regarding the implementation and future adoption of BD in the construction industry. This shows the need to educate present and prospective professionals in the area about emerging technologies such as BD that can alter the course of the industry. The inclusion of this and other technological developments into the education and training of present and future professionals can help lessen the resistance to change and increase the success rate of the implementation efforts.

6.2.4 Solution to company needs.

Company needs are the goals or objectives the business must achieve to function, generate profit, and deliver the company's mission (Kupersmith et al., 2013). These needs may vary from one organisation to another as well as changing over time depending on the direction in which the company evolves.

As explained by the following comment, Interviewee I7 identified the satisfaction of the company needs as one determining factor in the implementation of new technologies such as BD, meaning that this technology is capable of providing solutions such as process efficiency, time, or cost reduction which, according to Kupersmith et al. (2013), corresponds to the capacity needs and provision of new services which correspond to the improvement needs.

> *"The adoption of new technologies in this company has always been driven by the need for streamline construction and administrative processes, reducing time waste and managing resources". I7*

In addition, when asked about the key drivers that allow for the adoption of BD in the construction industry, Interviewee I3 identified some specific needs that would be solved by this technology.

> *"[…] the need of managing the information, the need of accessing the information". I2*

The ability of a technology such as BD to solve the needs of companies will depend on the specific objectives and needs of each company specifically. There is evidence in the literature that supports this trend where BD is identified as a solution to the need of managing the ever-increasing volumes of data generated by construction projects (Body & Crawford, 2012; Caesarius, 2017; Cheng et al., 2020), such as the need for

transparency (Khurshid et al., 2019) or because of its complexity. This technology can help to understand waste generation within the industry (Lu, 2019; Xu et al., 2020; Lu et al., 2021). This means that BD technology should be recognised as essential for project delivery which would in turn increase its adoption within the industry. Therefore, a homogeneous awareness of the concept, its characteristics and benefits is required. To achieve this, the industry should tap into the experience of other sectors that have already adopted technology in their processes, such as manufacturing and healthcare.

6.2.5 Organisation's technology-driven culture

The term company culture is commonly used to describe a series of elements, aspects or opinions that define a company and its employees. It can manifest in the decision-making process or in the interactions with other companies or clients (Doyle, 2020). In this specific case, the interviewees identified the company's culture of staying at the forefront of new technologies with technological orientation as the main factor in the adoption of new technologies such as BD. Some authors such as Tabesh et al. (2019) and Chen et al. (2020) agree that the adoption of new technologies such as BD is made easier in industries or companies that are digitally driven. For this aspect, the interviewees agreed, commenting on the following:

> *"Well, I believe we have a technology-driven culture in the company, also, the need for efficiency and transparency and the optimization of profit is what comes to my mind right now". I10*

Also:

> *"I believe than more than strategies for us what motivates us to invest and adopt any new technology is the culture of the company, the belief that offering something different and more advance than others will give us advantages that the clients can clearly identify". I14*

Another participant also recognises the role of the company's leadership and influence on culture and the successful implementation of BD, which Burmeister et al. (2015) agrees with. He expressed that a company with a leadership inclined towards innovation is more likely to invest and work towards the adoption of new technologies. Interviewee I1 identified this as a base requirement or key driver for implementation in his comment:

> *"It has to be from top to down, it has to be a mentality of the company, if the owners, if the manager, doesn't have that mentality of improvement it's going*

to be really difficult, it's going to be really tough to implement new software, new technologies and use of BD". I1

The culture, and more specifically the technological orientation of the company, plays a key role in the implementation of a new technology. It has not only been proven that the probabilities of implementation grow with the ability of companies to disburse themselves in the digital environment but that this also relates to the influence of the adoption and promotion of this culture by the decision-makers and leaders of the company. Therefore, construction organisations must make the leap towards a technologically driven culture where technological developments are placed at the centre of the organisations' mission, vision and operation procedures.

6.2.6 Client requirements

Client requirements are powerful elements that can force change within companies. In some specific cases where the client is an institution or government, these may require the implementation of methods or technologies that are beneficial for the delivery of the project. As in the case of BIM in the UK and the launch in 2011 of the "Government Construction Strategy" which required in the following years the inclusion of the technology in all government construction projects by 2016 (UK Construction Media, 2018), thanks to this requirement, 73% of construction companies employed this technology in 2020 (NBS, 2020). Interviewees I9 and I21 both identified the requirements of customers as a key factor in the implementation of new technologies such as BD, as evidenced by the following comments:

"I would have to say, customer requirements". I9

And:

"I would have to say, the demand from the market, maybe the clients could ask you to use it, if they know about it and understand that its use can be beneficial to them, […]". I21

In summary, it is clear that when a client presents a requirement for a project, the company is compelled to adapt its practices or delivery method and do what is necessary to meet this demand. In the end, organisations must consider their client's requirements as a motivation for change. Whenever a group of clients suggest or demand the use of any technological development, it is in most cases because they recognise some benefit. Construction organisations should have in place a feedback

system to consider and assess the comments and suggestions of the clients for use in present and future projects.

6.3 External Drivers

In the same way, this theme captured the participant's opinions about the factors outside of the organisations that could impact or influence the adoption of BD. The external drivers are industry motivation, the regulatory framework and technology change adaptability which will be discussed below.

6.3.1 Industry motivation

When asked about the elements that support the adoption of technologies such as BD, the participants identified industry motivation as a key factor due to its ability to compel companies to adopt certain practices such as BD or BIM. Once a company has achieved added value because of the implementation of a new technology, the industry takes on the responsibility to spread and promote this practice, awaiting similar results (Madanayake & Egbu, 2019). In the following comment, Interviewee I19 expressed his agreeance with this by commenting the following:

> *"In our case, it was the industry, every time we went to take a training overseas, we found that BIM was the method been adopted for more and more companies, many already witness the positive results of their adoption, and in some countries is already a government requirement, which indicates that this may be the course that the world industry is taking". I19*

Similarly, Interviewee I20 expressed his agreement with the next statement:

> *"We keep tabs in the industry developments and identify the thing that could work for what we do, we also evaluate the cost of investment, because is not always possible to buy everything you need to implement a new technology". I20*

The participants agreed that looking at the industry as a point of reference to determine what things they could implement in their organisations is a common practice. Once they identified an added value in the adoption of a new technology, it was a matter of assessing the feasibility of the adoption since is not always possible to follow or adopt every new practice or technology that comes into play in the construction industry.

Other companies from local and international markets can become reference points for technology development not only because of the perceived benefits but also due to the adoption efforts employed.

6.3.2 Regulatory framework

Regulatory framework refers to any official policy or regulation approved by the government to regulate an activity. In some cases, in its role of the biggest client of the industry, it can issue a regulation requiring the adoption of a practice or technology that can satisfy a need or that provides the ability to enable benefits that are aligned with the objectives of the institution such as data management or transparency. Phrases like the "Government has always been shaped by advances in technology" by Shepheard (2019) demonstrate the close relationship between governments and technological advances which are translated into regulations that in many cases determine the advances of industries towards the adoption of technologies. When asked about the key drivers of the implementation of new technologies such as BD, the participants identified government regulations as a defining factor. The adoption of BIM was given as an example which, under UK Government in its role of the biggest client of the industry, issued a mandate that spurred adoption of the technology, since it required for the technology to be adopted for all public projects in the United Kingdom (NBS, 2020). Regarding this theme, Interviewee I11 expressed the following:

> *"Well, since we haven't implemented BD, I can say that the drivers for adoption of implementing any new technology in this company are most of the time, government regulations, […] in order to attract clients […]". I11*

Also, Interviewee I5 made a brief comment identifying the government involvement in the adoption of a new technology within the industry with the following:

> *"[…] and norms and regulation for the construction-oriented parts of the Government". I5*

The recognition of being a government requirement as a key driver for the implementation of new technologies such as BD evidences the need that the company keeps up to date with new technological developments, even in areas like construction. Governments should push for the sustainable development of societies and the use of new tools and technologies that can help achieve this goal. The government should put in place a regulatory framework to ease the adoption of new

technologies by providing timely and assimilable information that helps organisations understand and identify if said technology would be beneficial for their business.

6.3.3 Technology Change Adaptability

Technology change adaptability is the technology's ability to integrate into a company, how easy is to comprehend, its compatibility with existing programs, and the ease with which staff can understand and master its use. This factor was identified as a key driver by the participants since it depends on companies being able to fully implement the technology and take advantage of its potential. For example, Interviewee I12 expressed the following:

> *"[…] Also, how easy the technology can be implemented in the company if it's compatible with existing software's or adaptable". I12*

Also:

> *"[…] I think that for us to implement something like that we should be able to identify the benefits, and how it would fit in this company or how we would use it, […]". I15*

The more adaptable or compatible a technology is, the easier its implementation will be within the company processes (Maroufkhani et al, 2020). It is necessary that all parties involved follow clear procedures explaining all elements such as the concept, benefits, requirements, similarities and compatibility between the existing tools and the new development, and the necessary steps for its adoption.

6.4 Discussion

Sources such as Vellante (2021) and Munawar et al. (2022) consider BD has the potential to become future of the construction industry as it could help overcome challenges such as low productivity and poor management. Following this same line, Ismail et al. (2018), considers the technology as a disruptor of the industry. The adoption of this technology as a core element of the construction practice will enable the industry to evolve in line with the needs of its users. The construction-related data produced by the industry is growing exponentially every year and since almost 95% of it is unstructured, it makes BD the ideal technology for its management, providing the benefits of the technology such as data-driven decision-making, resource, time and money-saving, process efficiency, and the prediction of outcomes to name a few (Carlstrom, 2020).

This chapter addresses the gap of understanding which relates to the factors that will promote the industry-wide adoption of this technology. The exploration of the key drivers of implementing Big Data in construction will help the industry set objectives and embrace measures that in the future will allow them to adopt this technology and take advantage of its benefits. This study was carried out by asking decision-makers on their opinion of what would be needed for the implementation of BD in the industry and more specifically, in their organisations. Based on their knowledge and experience, the participants identified nine key drivers that were divided into two groups, internal and external, according to whether the motivation came from within or outside the organisation.

The internal key drivers or determining factors that are likely to influence the adoption of BD from within the organisation are the knowledge of BD's benefits to the organisation, the impact on competitiveness, technology awareness, being a solution to the company's needs, the company's technological cultural orientation, client requirements, and profit expectations. Likewise, the external key drivers or factors that influence the adoption of BD from outside of the organisation are industry motivation, the regulatory framework, and technology change adaptability.

In some cases, the drivers identified by the participants coincided with those identified in the literature such as an increase in the company's revenue (Raguseo, 2018), benefit awareness and being a solution to the company needs (Madanayake & Egbu, 2019), as well as the company's technological orientation which allows them to take advantage of new opportunities offered by emerging tools, software, and gadgets (Wang et al., 2020), as well as the adaptability or compatibility of the technology (Maroufkhani et al, 2020). On the other hand, some new drivers came out including client requirements, industry motivation, and regulatory framework, all of which consist mostly of external agents that can influence their use.

The identification of these key drivers also brought out a series of needs that must be addressed so then the assimilation of the technology is achieved as part of the construction practices. The needs included practical examples detailing the experience of other companies with the technology, education and popularisation of the technology and its benefits and characteristics, the solution that it can provide to the needs of companies, and so on. Some external factors such as industry and the

international market can exert pressure on the implementation of new technologies, so the knowledge about it must be homogeneous.

The findings of this chapter will allow readers to understand the drivers for adopting a technology like BD in construction companies while exploring its potential. Moreover, these results provide a source of information for decision-makers on the direction the industry is taking, allowing them to prepare to make the necessary changes to their organisations.

6.5 Summary

The exploration of the key drivers behind implementing new technologies such as BD provides present and future professionals with the tools to identify what the forces are that will generate the change within the organisations. Some of these elements are what the organisation can tackle in the present, facilitating the adoption of the technology.

This chapter has provided an answer to RQ3, recognising the drivers that would impulse the implementation of BD in the industry. The nine key drivers identified by the participants were classified into internal and external according to the origin of the influence in relation to the organisation. The internal key drivers were the knowledge of BD's benefits to the organisation, the impact of competitiveness, technology awareness, it being a solution to company needs, the company's technological cultural orientation, client requirements, and profit expectation. The external key drivers or factors that influence the adoption of BD from outside of the organisation were determined to be industry motivation, regulatory framework, and technology change adaptability. Together, these nine elements shape the list of factors that satisfy RO3.

The results show that factors such as the knowledge of benefits would not only impulse the adoption of the technology but also can help overcome the resistance to change within organisations by providing attractive perks that decision-makers cannot resist such as the gaining of a competitive advantage over their competitors and recognition as innovators.

In the next chapter, the key strategies that are necessary for the adoption of BD in the construction industry and organisations will be presented.

CHAPTER 7. STRATEGIES FOR BIG DATA IMPLEMENTATION IN THE CONSTRUCTION INDUSTRY OF THE DOMINICAN REPUBLIC

7.1 Introduction

This section addresses research objective number four (RO4), “To explore key strategies for BD adoption”, which in turn answers research question number four (RQ4), “What are the key strategies for implementing BD in the construction industry? The chapter discuss the main strategies which, in most cases, can help create an action plan for adopting Big Data in the future. A determining factor in the adoption of new initiatives is the need for well-based strategies. Companies must establish clear objectives as well as responsibilities. To implement any new initiative, companies require well-based strategies where the aim and responsibilities are clearly expressed (Wattanajantra, 2020). Because of this, this study aims to explore the strategies for implementing BD in the construction industry based on the expertise of Dominican decision-makers.

The need to explore key strategies in the adoption of BD was discovered through the systematic review of relevant literature. However, as with the rest of the explored elements, the analysis of the literature revealed an extensive gap regarding elements that would guide or facilitate the adoption of BD in the construction industry, including strategies.

The findings presented in this section are the result of the analysis of the semi-structured interviews where twenty-one (21) professionals from leading organisations in the Dominican Republic’s construction industry shared their experience and points of view regarding what strategies will ensure the adoption of BD in their organisations and the industry. The data gathered from their responses was subsequently analysed using thematic analysis. Through this analysis, four key strategies for the adoption of technology were identified.

The documentation of these strategies for the implementation of BD in the construction industry of the Dominican Republic will serve as a guide for professionals who understand the impact that this could have on their projects and organisations and for those who wish to implement the technology in the future.

In this case, all of the strategies identified from the point of view of the participants can be considered as the basic elements needed for the implementation of new technology since they were requested to identify the main strategies that they believed were key in the implementation of BD in their organisations and the industry. These results represent clear evidence of the initial stage in which technology is present in the industry and the need to increase the level of awareness about technology in general (Silverio-Fernandez et al., 2019).

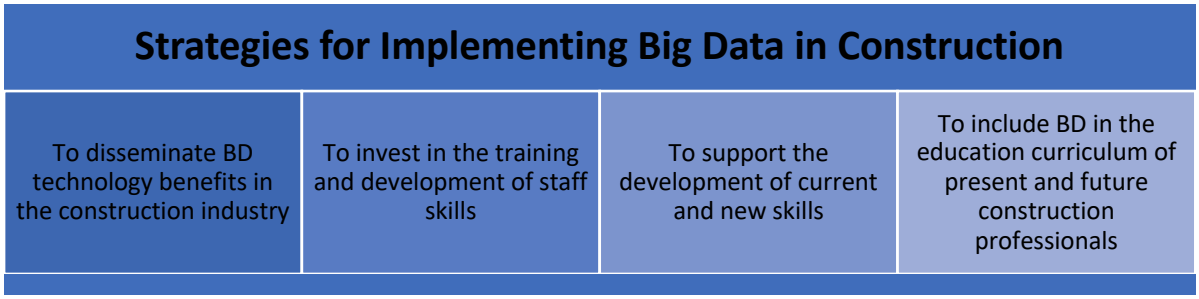


Figure 7.1: Key strategies Identified in the data analysis

This chapter is structured as follows: Section 7.2 presents the strategy of promoting the standardisation and popularisation of the concept and technology benefits. This is followed by Section 7.3 which presents the strategy of investing in the training and development of staff skills. Section 7.4 presents the strategy of supporting the development of current and new technologies. Section 7.5 presents the final strategy of including technology in the education curriculum of present future construction professionals. Section 7.6 discuss the relevance of these strategies and finally, Section 7.7 presents the summary of the chapter.

7.2 To Disseminate BD technology's Benefits in the Construction Industry

Both in the literature and previous studies, the importance of in-depth knowledge of the BD concept and its benefits has been highlighted (Silverio-Fernandez et al., 2019). Based on the low level of understanding that the industry has shown about the technology, as presented in Reyes-Veras et al. (2022), the identification of "Lack of awareness" poses a critical challenge (Reyes-Veras et al., 2021). Therefore, it is consistent for the participants to identify the popularisation and standardisation of the concept of BD and its benefits as a key strategy for adopting the technology in the industry. A clear understanding of the concept and the benefits that an organisation

can perceive from implementing new technology can help to overcome fear and resistance among the decision-makers. In this regard, Interviewee I7 expressed the following:

> *"[…] dissemination of concept and at the same time, benefits of its implementation". I7*

The need for a consolidated concept and benefit awareness in the industry is crucial for adoption (Reyes-Veras et al., 2022). Industry-wide benefits knowledge will help motivate organisations to invest in the technology. Furthermore, how BD can positively impact the delivery of construction projects and the overall decision-making capability of an organisation represents an advantage that can be easily translated to profit and a general sustainable improvement. For these impacts to become common, knowledge is recognised as an essential aspect to promote. In this regard, participant I13 also expressed:

> *"To implement BD, I believe that the main strategy would be to standardise the concepts and to make sure that everyone knows of the benefits of its implementation, to provide proof of the positive results of its applications and to emphasise which areas of the project process would benefit with its adoption". I13*

The previous statement emphasises the need for adequate knowledge about the concept and the benefits to be widely perceived. Also, there is the need to provide staff access to training where they are exposed to technological advances which they might be able to use in the future. This can help make the transition to these technologies smoother. Coinciding with the previous comments, Interviewee I18 expressed the following:

> *"[…] that people get to know the concept and its benefit better; a strategy could be popularising the term […]". I18*

With the above statements, the participants expressed that one way to counteract the basic levels of knowledge that the industry has about BD is through the standardisation and popularisation of the term. Disseminating the benefits of adopting BD will allow it to be easier to motivate organisations to start making the necessary changes for future implementation. This development will be achieved when organisations understand the benefits and impacts that it could have on construction projects. For this,

organisations must start by exposing their employees to technological developments and adopting technological drive as part of their culture.

7.3 To Invest in the Training and Development of Staff Skills

Another critical challenge facing BD adoption is the lack of technological expertise (Reyes-Veras et al., 2021), especially for emerging technologies as professionals are in the early stages of the learning curve (Chehri et al., 2021). For some technologies, companies must decide between bringing staff in from other areas such as IT and training them in the area of interest, i.e., the management of construction projects or training their team in the use of the new tool or technology (Bhat, 2020). This is one of the options for implementing BD and it will still require an investment in other elements such as software, equipment, etc.

Another option for adopting new initiatives in a company is to invest in developing the skills of the current staff by providing further education and training. The participants identified this strategy based on their experience with the previous technology implementation. Regarding the main steps they believe will be necessary for future adoption of the technology, there is the following statement by Interviewee I17:

> *"[…] we don't have any strategy other than personal training; we have workshops to learn new techniques, and we get encouraged by the company to continue our education with workshops, courses, MBAs, etcetera." I17*

The identification of staff training as a key strategy from the previous participant comes from his organisation's experience. This means that they already engage in the practice of keeping their employees up to date. This means there is a need to include BD and other emerging technologies in the training and educational programs of present and future professionals. Interviewee I20 also agreed by expressing the following:

> *"[…] the ongoing capacitation of workers and management staff… is the strategies we have in place, we try to follow the developments of the industry, but it sometimes takes years to get to know things like this, I mean we have trainings programmed about project planning and other tools that we could possibly acquire in the future, but we haven't heard anything about that [BD]". I20*

In both cases, the participants identified staff training as a systematic process in their companies which can be adapted according to the present and future needs of the business, confirming the effectiveness of the strategy and the development of staff skills as a critical element in the adoption as part of the advancement of the company. However, there is still a need to check how up to date the training programs are to ensure that the workers are exposed to and familiarised with concepts that are not only applicable in the present but that are also in line with the organisation's vision and the industry's future technology development. Moreover, organisations must expand their horizons and include innovative research when planning their future training.

7.4 To Support the Development of Current and New Skills

Many technologies could serve as a steppingstone for the future adoption of BD. In the case of the Dominican Republic, where it has been documented the use at different levels of technologies such as BIM (Silverio Rodriguez, 2020), the adoption of IoT and smart devices (Silverio-Fernandez, 2019), and the use of drones in the construction industry (Reynoso Vanderhorst et al., 2019) serve this purpose through the generation, processing, storage, and transmission of data. Also, the digitisation of the processes achieved with these tools plays a central role in the future adoption of BD by ensuring that there is enough historical information to be analysed. The investment in developing the current technologies is closely related to adopting BD, as expressed by Interviewee I2.

> *"[…] we are investing in the implementation of the Drones and to advance more in the technology part for topography (Land Surveying), because is something that we manage daily, and for example, we have projects that require it […] they require that we become more technological, more developed in that area, for instance, bridges, roads, everything that is infrastructure […] to develop that part of the technology in the topography area, those three are like the main axis [Project Management, BIM and Implementation of Drones] right now of [this company] five years from now… in the meantime, we are accumulating all that data that can be part of a big data set someday". I2*

Organisations acknowledge that they are not yet positioned to invest in BD technology. At the same time, they recognise that investing in current technologies, such as smart devices and surveying equipment, can help prepare for future technology

implementation by generating and storing digital data. The recognition that BD currently receives has resulted in companies including investments in the development of areas such as BIM and smart devices that could further evolve in the adoption of the BD technological skills in the short- or long-term within their future development strategies. I11 agrees with this and expressed the following:

> *"[…] to invest in tools that can use that storage data so we can create a process that will upgrade our decision-making process based on the previous experience". I11*

Investing in tools that will provide the present benefits for companies while serving as a foundation for the adoption of future technologies and digital skills development for staff is an attractive approach that could motivate organisations. With this strategy, organisations would not only be investing to receive benefits in the future but also the present. Companies would be incorporating tools that can be applied to projects and the current delivery processes. This element must be part of the organisation's vision and the responsibilities of decision-makers and leaders since they guide and facilitate the acceptance of changes by all staff.

7.5 To Include Big Data in the Educational Curriculum of Present and Future Professionals of the Industry

The last strategy, as well as the previous one (7.4), plays an essential role in implementing BD and similar new technologies. The current professionals need time and resources to become familiar with new concepts, tools, and technologies. Therefore, organisations must ensure that the future generations have the necessary skills to meet the needs of the projects that they will collaborate on. Exploring new technologies to train future professionals will mean they will become familiar with them, facilitating adaptation. Interviewee I18 expressed an example of this in the following statement:

> *"[…] start teaching about it in the last modules of university, that way, the people that will start their work carrier already know about this and have a better understanding that they can contribute to their workplaces". I18*

In the same line, Interviewees 09 and 21 expressed the following:

"I believe that if they teach us these types of trends when we are studying when we have to work with them in the workplace, we will have fewer problems assimilating because it is something we already know instead of having to learn something from scratch". I9

"I think the main thing to do is to submit employees to training that helps them understand the technology, so when the company decides to implement it, it will be able to make use of its investment at once… The skills they gain from this [training] can help them improve some aspects of their current performance as well as their relationship with digital elements of projects". I21

The inclusion of BD in training, as well as the educational curriculum of future construction professionals, will result in a positive impact on the future adoption of this technology since these future professionals will possess the required level of awareness and knowledge about the different aspects of the technology. Elements such as the concept, characteristics, and benefits, which have proven to be necessary for implementation, would help reduce the resistance to change and help promote the industry-wide implementation of BD.

A consistent element of the strategies presented before can be highlighted between the literature review results and this study. The need for investment in the training and development of skills among the employees came to light when collecting both primary and secondary data (Hwang et al., 2021), therefore it can be deduced that this strategy has great importance when it comes to the implementation of technology in the construction industry. On the other hand, the remaining strategies showcase a low knowledge and awareness of the subject.

Finally, the documentation of these strategies for the implementation of BD in the construction industry of the Dominican Republic will serve as a guide or action plan for professionals who understand the impact that this could have on their projects and organisations and those who wish to implement the technology in the future.

7.6 Discussion

The need to manage today's sustainable development requirements (Oladokun et al., 2021), as well as the role of construction in the achievement of the goals that most

governments have set, plays a vital role in the modernisation of the industry and the search for tools that allow for the managing and meeting of these expectations.

To solve this challenge, the industry is looking into embedding trends such as industry 4.0 and the circular economy (Newman et al., 2021; Osobago et al., 2022), focusing on applied technologies like BIM, IoT and smart devices (Silverio Fernandez et al., 2019; Oke & Arowoiya, 2021). This is followed by starting to look further into innovative technologies such as BD (Burger, 2019; Wong, 2020).

Many sources highlight the ability of BD to generate change in the industry that allows for the ability to meet future industry needs based on the positive results of BD in other disciplines (Tamiminia et al., 2020; Caesarius & Hohenthal, 2018; Pigni et al., 2016; The Economist, 2012; Raguseo, 2017). In contrast, limited sources exist about the factors that enable BD adoption within the construction industry, indicating the presence of a gap.

Identifying strategies for adopting new technologies such as BD in the construction industry allows the industry and the companies therein to develop an action plan to adopt this technology as part of the project delivery process (Wattanajantra, 2020). When comparing the results of this study with the strategies identified in the literature, common ground was found in the development of staff skills (7.3 and 7.4) (Hwang et al., 2022). In contrast, other strategies identified, such as knowledge and investment, align with the industry's basic level of awareness (Reyes Veras et al., 2021).

First, the need for in-depth knowledge of BD technology and a homogeneous concept has been highlighted in the literature (Silverio-Fernandez et al., 2019) and in previous sections of this research (Reyes Veras et al., 2021; Reyes Veras et al., 2022). As an acknowledgement of this and based on their experience, the study participants have expressed the need for a strategy that addresses this demand. The dissemination of the benefits of technology in the industry seeks to improve the general knowledge of BD, to overcome the challenges such as a lack of awareness, and to contribute to the decrease of the resistance to change identified previously (Reyes Veras et al., 2021). This is because familiarisation with the concept reduces the chance of its rejection.

Likewise, staff training was identified as a recurrent element in some of the participant companies (7.3). This is reflected in the choice of staff training as a strategy that would benefit the implementation of BD in the industry. In most cases, the development of

staff skills is considered within the investment of new technologies. Still, in this case, the impact of early BD training for construction professionals would benefit the future adoption of the technology and the overall digitalisation and efficiency of the company processes. In other cases, construction companies already offer ongoing staff training and it would be a matter of focusing on developing the skills relevant to BD.

The literature also supports this strategy. Hwang et al. (2022) acknowledges it as a critical component both from the governmental and organisational point of view, confirming that the implementation of this strategy could represent the difference between the successful adoption of BD in the construction industry and a failed attempt at improving the processes and decision-making.

Another critical strategy identified by the participants is the development of current technologies that will enable the adoption of BD in the future (7.3). Existing initiatives, such as BIM, smart devices, and drone implementation (Silverio Rodriguez et al., 2020; Silverio Fernandez et al., 2019; Reynoso Vanderhost et al., 2019) serve as the basis for the future adoption of BD in terms of both adapting the data generation and transmission systems necessary for the technology to be implemented and enabling the familiarisation of companies with the digital environment.

Including the critical elements of BD within the curriculum of future professionals in the industry ensures that they are familiar with it when they migrate to it. This minimises any resistance to adopting the technology (7.5). This is also acknowledged by Hwang et al. (2022) in both government and organisation-oriented strategies, meaning that this should represent a fundamental policy for organisations moving to adopt the technology. The low level of knowledge that the industry has about the concept of Big Data and its benefits represents one of the most significant challenges to implementation.

The strategies presented in this study are mainly directed at construction organisations. Other stakeholders, such as the government, require the analysis of case studies that quantitatively reflect the characteristics behind the implementation of BD in the industry. This will allow for the creation of policies that promote the adoption of BD. Nevertheless, other variables such as company size, usability, and cost should also be considered (Silverio Fernandez et al., 2019).

In summary, the critical strategies presented above reflect the current state of BD technology in the construction industry of the Dominican Republic. They focus on the essential characteristics such as improving awareness, promoting investment in tools that benefit both the current projects of companies and the future adoption of technology, developing the capacities of the people to adopt this and other technologies, as well as the expansion of the concept towards the area of education regarding training future professionals in the industry. Nevertheless, the participants' low level of BD awareness represents a significant limitation in this study. So far, these strategies are consistent with the challenges previously identified in this broad research (Reyes Veras et al., 2021). The lack of awareness and technological expertise are evidence that reasserting these strategies is essential when implementing BD technology in the industry.

7.7 Summary

This section presented the key strategies for Big Data adoption according to Dominican industry experts. As a result of the query represented by RQ4, four main strategies were identified. These strategies, which include the promotion of standardisation and popularisation of the BD concept and its benefits, investment in the training and development of staff skills, support for the development of current technologies, as well as the inclusion of technology in the education curriculum of present and future professionals, satisfies the RO4. Moreover, this will help companies with an interest in adopting Big Data as part of their organisations in the future to develop an action plan and identify the steps that they need to follow to achieve the successful adoption of the technology.

The key strategies presented above reflect the current state of BD technology in the construction industry of the Dominican Republic. They focus on the basic elements such as improving awareness, promoting investment in the tools that benefit both the current projects of companies and the future adoption of technology, developing the capacities of the staff to adopt this and other technologies, as well as the expansion of the concept towards the area of education in charge of training future professionals in the industry. The identification of these elements will contribute to increasing the scarce body of knowledge for research professionals who focus on the exploration of

defining elements for Big Data adoption as well as possible future professionals in the construction industry.

The following chapter (Chapter 8) will focus on exploring the challenges faced by the industry in its journey towards the adoption of BD.

CHAPTER 8. CHALLENGES FACED BY THE ADOPTION OF BIG DATA IN THE CONSTRUCTION INDUSTRY OF THE DOMINICAN REPUBLIC

8.1 Introduction

In this section, the challenges faced by the adoption of the BD concept in the construction industry will be presented and discussed. In turn, this section addresses research objective number five (RO5), “To explore the challenges for implementing BD in the construction industry”. This section also satisfies research question number 5, “What are the challenges that organisations and the construction industry face when adopting BD?” The identification of these challenges enables the industry to prepare ahead and when possible, avoid them altogether.

The analysis of the literature discovered the lack of sources that point out the determining factors for the adoption of BD in organisations and the construction industry where one of the main elements is the challenges involved. To close the gap between the promise of a technology and its achievement, some challenges must be overcome (Leonard-Barton & Kraws, 1985). Each change that is implemented, regardless of whether it is at a company or industrial level, brings its own challenges. In this case, the implementation of BD in construction companies and the wider industry is not an exception (Baig et al., 2019; Small, 2019).

As a result of the analysis of 21 semi-structured interviews performed with industry professionals, seven challenges were identified: a lack of BD awareness, resistance to change, the high cost of investment, a lack of government support and regulation, security concerns, and a lack of technological expertise are the key challenges facing the adoption of the technology. The lack of motivation from the stakeholders are the main barriers for the adoption of the technology in the construction industry. The data collected from the interviews was subjected to thematic analysis to explore and understand the key elements mentioned before. The challenges identified in this study are the key elements that influence the adoption of technologies like in this case of BD. Their understanding will serve both the companies and the construction industry to prepare an implementation plan based on its reality where the necessary tools are presented for the successful implementation of the technology.

This chapter is structured as follows. Section 8.2 addresses the challenge of a lack of BD awareness, Section 8.3 presents the challenge of the high cost of investment, Section 8.4 discusses the challenge of resistance to change, followed by Section 8.5 which examines the lack of government support and regulation. In turn, Section 8.6 deliberates the challenge of a lack of technological expertise, Section 8.7 addresses the security concerns, and Section 8.8 introduces a lack of motivation from the stakeholders. This is followed by the general discussion of the challenges in Section 8.9 and finalises with Section 8.10 with a summary of the chapter.

8.2 Lack of Big Data Awareness

Possessing awareness around technologies such as BD implies being able to identify the value that this technology can contribute to the business (Silverio Fernandez et al., 2019). As demonstrated in a previous study in which the level of awareness about BD and its characteristics were measured (Reyes Veras et al., 2021), there is an overall low level of awareness in the construction industry of the Dominican Republic. Considering that awareness refers to the knowledge or perception of a fact or situation, in this case BD technology, this detail represents a challenge to overcome in order to achieve an industry-wide adoption of the technology. The participants identified lack of awareness as an obstacle between the current state and future adoption of technology at both the company and industry level. For instance, some of the interviewees expressed themselves regarding the lack of knowledge about the concept of BD and its characteristics:

> *"The ignorance on the subject, not knowing the relevance, not knowing that everyone is a Big Data generator [...] I2*

> *"I would say ignorance of the concept and its benefits". I8*

> *"I think the first challenge will be to know about this topic and soak up well about the benefits that can be obtained with the big data implementation". I12*

> *"Well, in terms of big data I would say is that there is not enough information about it, and for the new technology aspect in general is the same that I said*

before, sometimes we like to wait until there is no doubt that this new thing in which you want to invest works". I14

"I think the main challenge is that is something very new and people now too little or nothing about it, and if you don't know it there is really nothing else you can do". I20

Unawareness of the basic concept of BD technology indicates that for the technology to be adopted by the industry, it is necessary to resolve this situation by promoting the popularisation of the concept, its benefits, and characteristics. Companies must be proactive when it comes to researching technologies that could improve the services they offer, as well as when disseminating knowledge about such technologies.

Interviewee I13 also stressed the fact that although the technology may be known in other areas, its impact on the construction industry is unknown:

"Well, I think that the main thing is the lack of knowledge on the topic, I bet that almost anyone haven't heard of the implementation of BD in construction, they may have heard of its implementation in other areas like my case, but I really doubt that you will find many people that know about how this can be used in construction projects. I13

The aforementioned study on the measurement of BD awareness levels and its characteristics (Reyes Veras et al., 2021) also showed that there is also a low level of knowledge of the technology in other industries. This makes its popularisation in construction even more difficult.

The lack of a deep understanding of BD and its functions, features, and benefits inhibit the future adoption of the technology. Unlike other challenges that may be addressed in the future, this is a problem that must be solved beforehand since the implementation of the technology depends on it. Nowadays, there are many examples of BD applications in other industries that could be replicated in construction. Furthermore, there is an increasing number of examples of the impact of this technology within the industry. Still, it is necessary that companies adopt the habit of exploring new techniques and tools which requires a change in mindset and becoming technologically driven.

8.3 High Cost of Investment

It has been shown that companies and industries with a marked digital orientation find it easier to incorporate new technologies into their processes (Tabesh, et al., 2019; Chen et al., 2020). There is no doubt that the investment cost of a technology and its requirements greatly influences its implementation. Because of this, many sources have identified the initial cost of acquiring BD infrastructure and training (TatvaSoft, 2021), the cost of using and maintaining this infrastructure (Bello et al., 2021), as well as the lack of financial planning of the companies for the implementation of new technologies (Chuah et al., 2021) as the challenges to overcome in the adoption of the BD concept in the construction industry. Moreover, this challenge was identified by many participants during the data collection process as one of their biggest concerns regarding the adoption of new technologies. This includes the case presented by Interviewees I13 and I20 in the next statements:

> *"For us the main thing is the relationship cost/return of the investment, we evaluate some other aspects but that is in most cases what prevents us of dabbling in any new technological development". I20*

> *"[...] but also, the possible costs of implementation, how much you would need to invest to adopt this technology and at this point there is little, or none proven information of its results for the construction [...]". I13*

Interviewees I6 and I18 also provided some details on the investment necessary and why the cost may be outside of the company's financial capabilities with the following comment:

> *"[...] Also, investment in hardware and software. By requiring that the information is centred and stored correctly or beneficially for the company, high-speed computers are required for data management and software is required to help and establish the channels and protocols for the data. Both (hardware and software) are very large and short-term investments that companies must contribute". I6*

> *"[...] sometimes it requires a great investment out of the economic capacity of the companies, since, you need to update your hardware, buy software's and train your employees on how to use those programs, usually with and official*

source that normally are outside the country, so of course, there are many aspects involved, but the economic is key, it could determine whether or not you can make the adoption". I18

Lastly, Interviewee I14 argued about the reality of many companies in which they do not have financial planning or a budget in place dedicated to new technological investments:

"[...] and finally capital investment required most companies don't have capital dedicated to try new methods, tools, and technologies, they usually make an investment after something is proven to work in a positive way, avoiding that way any risk". I14

The financial capacity of a company largely determines its ability to invest in new technologies. Even so, when some technologies are not compatible with the company's current systems and require a high investment to adapt the infrastructure, this factor becomes even more decisive. This makes the case of the construction industry more disadvantageous since it has been shown that even large companies that have more of a possibility of investing in the adoption of BD still have basic systems. In some cases, this is analogous for carrying out their activities which would exponentially increase the investment to adapt their equipment to the needs of technology. Having said this, this was determined by many authors (TatvaSoft, 2021; Bello, 2021; Chuah et al., 2021) and the data analysis process that the technology must have a certain affordability for it to be considered for adoption.

8.4 Resistance to Change

The construction industry is well known for its traditional practices that produce resistance in companies every time they seek to introduce a new method or adopt a new technology (Silverio Fernandez et al., 2019). This resistance is an element to overcome when looking to create changes in the way that the processes are normally carried out. Many of the participants identified this factor as a challenge for the implementation of technologies such as BD both in their organisations and in the industry. For instance, when asked to describe the challenges faced by the industry and their organisations in the adoption of this type of technology, I3 expressed the following:

"[...] like the ability of the employees to accept it and decide to use it, because independently, sometimes you have an integrated system, where you can find everything, but people keep using other technology they feel more comfortable with [...] The people keep using WhatsApp, people keep using the mail, people keep using another thing. So yes, the resistance to change [...]". I3

This indicates that even when a more efficient way of carrying out a process is adopted within a company, its benefits will not necessarily be fully exploited since people tend to stick with the methods with which they feel most comfortable, often to the point of ignoring and wasting the opportunities offered by the new system. Similarly, I5 and I6 also commented the following:

"There is a resistance to implementation because it represents a process and additional work time within the large workload that already exists in a construction project. Likewise, I have had clients prone to make multiple changes at all stages of a construction project that are reluctant to believe in the efficiency of information management because they expect the execution of constant change immediately which is unsustainable". I5

Also,

"[...] I would say first work culture, since employees at all levels always feel dissatisfaction when trying to change current work methodology [...]". I6

In this case, the participants also expressed the reason why resistance occurs on many occasions. This is related to the increase in work incurred by the adoption of technology, since, in many cases, it is expected that the adoption process does not interrupt the other productive activities of the company.

The previous statements show that either out of habit or because the implementation would imply an increase in the work volume, there is a resistance that hinders these processes. It is recommended that to overcome the resistance to change, it is necessary to overcome opposition by engaging the stakeholders who are against the proposed change. They need to engage effectively with the employees by listening to their feedback; this includes not introducing everything at once. Time and preparation are key and companies should prepare and then act. After this, it is still necessary to introduce proper management and support to make sure that everything runs

accordingly. Finally, effective communication about the new things to be introduced will ensure that everyone understands their role and what to expect of the change.

8.5 Lack of Government Support and Regulation

Governments, in many cases, are the precursors of the implementation of new technologies such as in the case of BIM (NBS, 2020) in the United Kingdom. This drove the adoption of this technology throughout the industry. Furthermore, some may argue about the close relationship between the government and technology (Shepheard, 2019) in cases where technology can provide a solution to the needs of the institution. On the other hand, when the government does not recognise or promote the adoption of a technology, an environment of incompatibility is created that can force companies either to double up the work or remain in the original format. This is the situation acknowledged by the participants who issued the next comments:

> *"Sometimes you try to implement something new and at the end you need to use the old methods anyway because they are not compatible with what the government ask and can process". I7*

> *"I would say the government blockade, somethings you invest in something new but the government doesn't recognises the new format in which you are now working so you end up having to go back to the old ways to be able to submit and get approval to start the project [...] Sometimes they don't even tell you, when you ask about the status sometimes even months after the submission is when you learn that they don't recognise that format". I21*

Added to this situation is the lack of incentive undertaken by the government. The participants expressed that since the government institution is one of the main beneficiaries of the construction industry development, it should promote the adoption of technologies that, as mentioned above, align with its needs. With the following statement, both Interviewees I14 and I19 highlighted the government's responsibility for the adoption of new technologies within the industry.

> *"I think quite a few come to mind but needed to say the most important are lack of incentives from the government, they should be the most interested in the evolution of the industry [...]". I14*

"[...] the lack of incentives from the government, as I said in some countries the government is asking the companies to adopt some technologies, but they have regulations in place to make sure that the companies can actually do it". I19

According to the above, it can be concluded that governments should promote and regulate the use of technologies that are beneficial for the development of industries. This translates into direct benefits for society. Governments should also promote, encourage, regulate, and back up the adoption of technologies like BD that contribute to transparency, better decision-making, and the overall management of digital information.

8.6 Lack of Technological Expertise

The implementation of a new technology such as BD within a company implies an adjustment process that requires updating not only the equipment but also the knowledge of the human resources within the company. This is so then the latter can take full advantage of the benefits of this new technology. The hiring of trained employees is also complicated since according to Gohil and Akhilesh (2018) "skilled BD analytics workers are hard to find." This need has been identified as a challenge for two main reasons. First, there is the aggregated cost of training the staff to use the technology (which falls within the high cost of investment discussed before) and second, there is the ability of people to learn to use this technology. It has been demonstrated that many technologically-driven companies characterised by having young and technologically active staff have more ease regarding the adoption of new technologies (Silverio Fernandez et al., 2019). It is therefore easy to assume the opposite case where, in companies that tend to adhere to traditional methods and with more senior staff, it is more difficult for them to adopt new tools and processes.

"Maybe training, that the person, I mean, the people that need to access some type of information system knowing how to do it, will prepare them to do it". I3

Also,

"Well we always need to determine if the adoption, or any change ... that we try to introduce to the company, has to be assessed in terms of time, investment and the capability of the workforce to adapt that change, because we have in the past invested in some software's to make more efficient some process but

the investment required to train the employees in its use is too high, and we end up with a software that only two or three people know how to use, which offers little advantage to the company as a whole". I16

The opinion expressed by the participants in the previous comments is mostly reflected in environments where the company staff is not constantly trained in order to keep up to date. The challenges here regarding the adoption of new technologies increase since it is easier to learn new technological developments little by little and over time than it is to make a great leap from an old system to a modern one without knowing the developments that have been made in between. It is therefore necessary for companies to maintain a good training program that is aimed at exploring and implementing the small developments that are being generated in the industry which in turn facilitates the ability of the staff to grasp the new technologies that, like BD, require a more technical level of digital skills.

8.7 Security Concerns

There are many concerns that surround data management technologies such as BD since some sources assure readers that there are no protocols to ensure that the analysed data does not contain private or sensitive information about the users who generate it (Small, 2019), plus the consideration that the data is not protected or trustworthy (Brandín & Abrishami, 2021). This apprehension is identified as a challenge for both the primary and secondary data so long as the procedures that ensure the rights of the people and companies that generate personal and commercial data are not violated and cannot be identified (Bello et al., 2021). In this regard, Interviewee I21 stated the following:

"[...] it raises some questions about security and the management of the data that we allow some apps and companies to have about us [...] of course, until you can assure that this technology won't present any risk to companies and their private information, I don't see it really been used broadly or implemented in construction". I21

The identification of the security threat posed by the technology goes in hand with a deep understanding of its operation. Still, some clarification is needed regarding how the analysed data is handled by the BD tools. With this, plus the assurance of the

proper use of this data, solutions can be provided by the awareness and popularisation of the BD processes.

8.8 Lack of Motivation of the Stakeholders

The lack of motivation of the stakeholders on the adoption of new technologies such as BD was the final challenge identified during the analysis of the interview transcripts. It takes a long time to implement technologies like BD and on top of that, there is little to no support or motivation from the stakeholders involved. Moreover, most construction organisations don't usually have funds for the adoption of new technologies. The tradition that companies only adopt changes that produce proven positive changes are among the concerns raised by the participants when asked about the challenges to BD implementation. On this last topic, Interviewee I10 expressed the following:

> *"There is no evidence of positive results of implementation in the construction industry that I am aware of… I don't see the point in investing in something like this, when what we are doing now works and no one other than us gets involved in how we delivery the projects". I10*

The previous comment shows the need to provide examples showing the benefits of the implementation of new technologies in the case of BD as well as many other technologies. Examples exist but are not yet popular, so the real challenge lies in making the success stories available to promote industry-wide implementation. Moreover, stakeholders should be involved in every part of the process since every decision made impacts all. By exploring and learning about new technological developments, stakeholders can open up discussions about the way that their needs are satisfied by the organisation. The way in which a project is delivered should be of concern to all stakeholders, making the need for creating or improving the communication channels between all parties evident. Organisations should provide an efficient way of encouraging and managing the flow of information.

8.9 Discussion

The use of thematic analysis to examine the collected data allowed the identification of the main challenges to be overcome in the adoption of the BD concept in the

construction industry. Through this methodology, it was possible to deeply explore the opinion of the participants identifying the ideas and patterns that resulted from the themes presented before (Caufield, 2019). Seven main implementations were found, defying the elements and other areas of concern. These will allow organisations to plan ahead and make the necessary preparations whenever they wish to incorporate technologies such as BD in their organisations.

From the data analysis, it can be observed that only two of them (the high investment cost and the security concerns) correspond with those identified by the literature. This can be attributed largely to the low level of awareness possessed by the participants in the construction industry in the Dominican Republic about BD and its characteristics (for in-depth analysis, refer to Chapter 5). Likewise, the need to promote technology and educate on its concept and operation is generated. Understanding factors such as governance, latency, and dark data requires experience that is only achieved through education and the use of technology. The primary focus should be to make it popular by demonstrating the benefits of BD and the return of the investment. This would encourage the adoption of BD in organisations and the industry as a whole.

These basic challenges represent the state of the industry in terms of the digitisation process. As the industry and organisations begin to resolve these basic elements, other challenges more related to the requirements of the technology will arise.

8.10 Summary

The adoption of Big Data (BD) in the construction industry has been identified as a possible solution to the current needs of projects but the integration of this technology has proven to be a challenge, especially in industries such as construction that are not technological driven. The understanding of the key challenges for the adoption of BD in the construction industry could help to exploit the benefits offered by this technology.

To identify these challenges, qualitative research was undertaken due to the paucity of scientific data. Twenty-one individuals representing 19 companies who have a great impact in the DR construction sector were interviewed. The collected data was subjected to thematic analysis and from this, seven main challenges were identified; a lack of BD awareness, a high cost of investment, resistance to change, a lack of

government support and regulation, a lack of technological expertise, BD security concerns, and a lack of motivation from stakeholders. The challenges identified in this study satisfy both RO5, exploring the challenges when implementing BD in the construction industry while answering RQ5, ‘What are the challenges that organisations and the construction industry face when adopting BD?’ Moreover, these key elements will help companies to better plan their technology adoption process, mainly by considering aspects such as the need to tackle the lack of awareness by disseminating and promoting the concept of BD which will generate a better understanding of technology by making sure that present and future professionals understand the technology and its benefits. This study provides insights into the challenges that need to be overcome for the successful adoption of BD technology which would help companies prepare for its future adoption.

The following chapter (Chapter 9) will focus on the development of a readiness assessment tool for the adoption of BD in organisations in the construction industry.

CHAPTER 9. ORGANISATION'S READINESS ASSESSMENT TOOL FOR BIG DATA ADOPTION

9.1 Introduction

This chapter addresses Research Objective Number Six (RO6), "To develop and validate a Big Data Readiness Assessment tool for construction organisations." This chapter proposes an assessment tool that would allow construction organisations to evaluate their readiness to adopt BD. Both (Moore, 2014; Kalema & Mokgadi, 2017) agree that a roadmap for adopting BD technologies is essential in achieving this goal. Nasrollahi et al. (2020) also concurs that the ability to assess readiness is a critical step in adopting BD. The findings presented in this chapter were developed through a systematic review of the literature and the analysis following the primary data collection.

The literature review consisted of a query to the relevant database sources such as Science Direct, Google Scholar, Scopus and ProQuest, and the World Economic Forum's Future-Readiness Benchmarking Tool (2022). Twenty-one semi-structured interviews with professionals in the management area of construction organisations in the Dominican Republic were analysed to identify the status of BD in the construction industry, the influencing factors for its adoption, and the need for guidance when undertaking this task.

In the systematic literature review, Tornatzky and Fleischer's TOE framework constitutes the foundation for the proposed readiness assessment tool (Tornatzky et al., 1990). It considers the areas of technology, the environment, and organisation as essential, so then technological innovation changes can occur. The tool delivers a way for organisations to measure their ability to adopt BD and highlights any weaknesses.

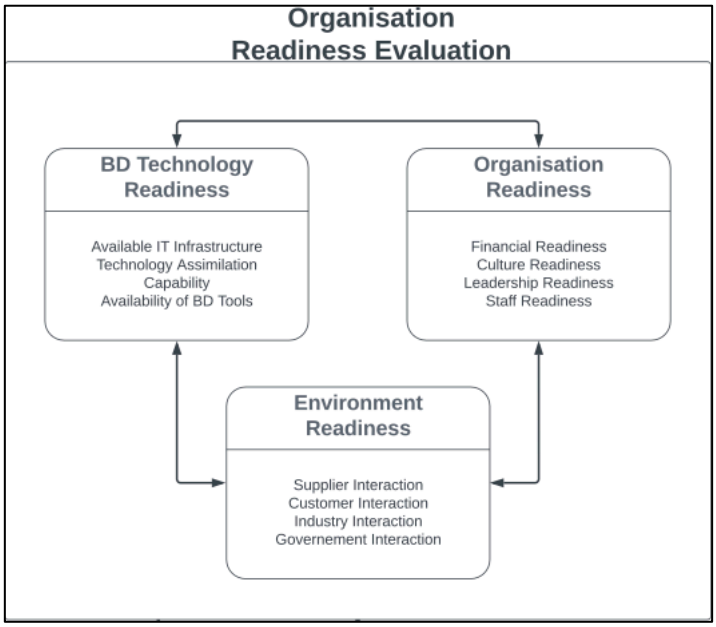


Figure 9.1: Tornatzky and Fleischer's Technology-Organisation-Environment (TOE) framework (Tornatzky et al., 1990)

This chapter is structured as follows: Section 9.2 addresses the reason behind the need for a BD readiness assessment tool. Section 9.3 presents the structure of the readiness tool for BD adoption and addresses the TOE elements mentioned before. Section 9.4 discusses the evaluation process of the tool and finally, Section 9.5 summarises the findings of this chapter.

9.2 Rationale of the Big Data Readiness Tool

The exponential growth of information technology generates a reciprocal growth of structured and unstructured volumes of data, otherwise known as Big Data (Garyaev & Garyaeva, 2019; Kalema & Mokgadi, 2017). This technology offers numerous opportunities in the Architecture, Engineering and Construction industries. It promotes better decision-making and process efficiency in almost every industry that has implemented it (Caesarius & Hohenthal, 2018; Pigni et al., 2016; Raguseo, 2018). However, successful adoption is not straightforward since it has to consider the technological and digital capabilities of the industry (Caesarius & Hohenthal, 2018; Tabesh et al., 2019; Chen et al., 2020).

Several studies have highlighted the intrinsic resistance to change in construction which makes adopting new technologies in the industry more difficult (Srinavin et al., 2021). Moreover, a lack of awareness, high cost of investment, and resistance to change were among the main challenges inhibiting BD technology adoption in the

Dominican Republic's construction industry (for a more in-depth review, see Chapter 8). Sarrakh (2021) explains that an early readiness assessment can represent a solution to these challenges.

Assessing readiness is a process through which the ability of an organisation to adopt a change can be determined since it provides an opportunity to address the issues that an organisation may face when implementing a new plan (HRSA, 2012). The purpose of this assessment is to define potential obstacles that could undermine the success of a proposed project. Big Data is a complicated subject and its effective execution is not always a given (Olszak & Mach-Król, 2018). Sources such as Nasrollahi and Ramezani (2020) and Kalema and Mokgadi (2017) believe that assessing the readiness for adopting BD plays an essential role in its adoption. This is due to the many factors that affect BD readiness which can vary depending on the industry and even the organisation (Srinavin et al., 2021).

In the case of construction organisations, measuring the readiness for change in the case of BD adoption of the relevant stakeholders in construction is essential for its successful implementation since the human factor plays a central role in adopting such technologies (Britel & Cherkaoui, 2020). Therefore, a BD readiness assessment tool would be decisive for successfully adopting the technology in the industry (Moore, 2014; Kalema & Mokgadi, 2017; Nasrollahi & Ramezani, 2020).

9.3 Development of the Organisation's Readiness Tool for Big Data Adoption

The development process for the readiness assessment tool consisted of a series of steps. The first step involved a critical assessment of the literature aiming to identify the elements influencing the adoption of BD in the construction industry. The literature review consisted of a query of the relevant database sources such as Science Direct, Google Scholar, Scopus, and ProQuest, as well as the World Economic Forum's Future-Readiness Benchmarking Tool (2022). According to Olszak and Mach-Król (2018), the critical assessment of literature that helped identify essential elements of BD adoption in organisations was based on publications made in the English language. The searched topic was the readiness assessment of BD in construction

and other recent industry developments, such as BIM, between the years 2012 and 2022.

The second step consisted of the analysis of the primary data. Semi-structured interviews with 21 professionals in the management area of construction organisations in the Dominican Republic were analysed to pinpoint the critical factors for adopting BD in the construction industry. Seven assessment characteristics were identified during both processes from the 11 included in the tool, such as technology awareness, education technology accessibility, feasibility, affordability, government regulation and support, and leadership. However, the other four essential elements were highlighted in the literature as extremely important and therefore have been included in the tool to ensure its viability.

The third step involved the selection of a baseline readiness instrument. The technology-organisation-environment (TOE) framework was selected for this purpose because it is aimed at evaluating the different factors influencing organisational decision-making (Baker, 2011). The framework constitutes the foundation for the proposed readiness assessment tool. It considers the influence of technology, the environment, and organisation contexts as essential so then technological innovation changes can occur.

The TOE framework was first introduced in 1990 by Tornatzky and Fleischer in their book "*The Processes of Technological Innovation*" which describes the process that an organisation must undergo to achieve innovation (Tornatzky et al., 1990). The technological context is comprised of relevant internal and external technologies as well as all necessary resources for its functionality which aligns with some of the findings of this study (Baig et al., 2019).

Organisational context involves the firm's resources, setting, and characteristics (Baig et al., 2019; Tornatzky et al., 1990). Meanwhile, the environmental context engages the organisation's external influences, such as industry, government, customers, and suppliers (Baker, 2011; Baig et al., 2019). According to Baig et al. (2019) and Tornatzky et al. (1990), the perceived benefits cannot be received through technological innovation only. Instead, it requires support from other areas as the organisation's inner and outer environment directly impacts the adoption of new technologies.

The selection of this framework was due to its versatile characteristics which allow for the choice of the elements to be evaluated in each context concurring with the original belief that each technology studied has its own unique set of measures (Tornatzky et al., 1990). This characteristic allows the framework to be adapted for measuring the readiness of a new technology like BD to the point of being considered one of the most common methods for the adoption of information systems (IS). It is where the adoption decision is explained both at the individual and organisational level (Baig et al., 2019).

The fourth step involved interplaying the elements identified in the literature review and data analysis within the framework. The tool is divided into different levels that can be evaluated individually or as part of an overall assessment of the organisation.

Table 9.1: Levels of the BD readiness assessment tool

Level	Assessment
1	Organisation
2	Technology, Organisation, and Environmental Components
3	Specific Criteria

Finally, the developed tool delivers a way for organisations to assess their readiness to meet the changes and their ability to adopt BD, highlighting any weaknesses. Users will be presented with a statement describing the qualities of their organisations and they must state whether they agree or disagree. The following linear scale was used to measure readiness:

- 1 = Strongly disagree
- 2 = Somewhat disagree
- 3 = Neither agree nor disagree
- 4 = Somewhat agree
- 5 = Strongly agree

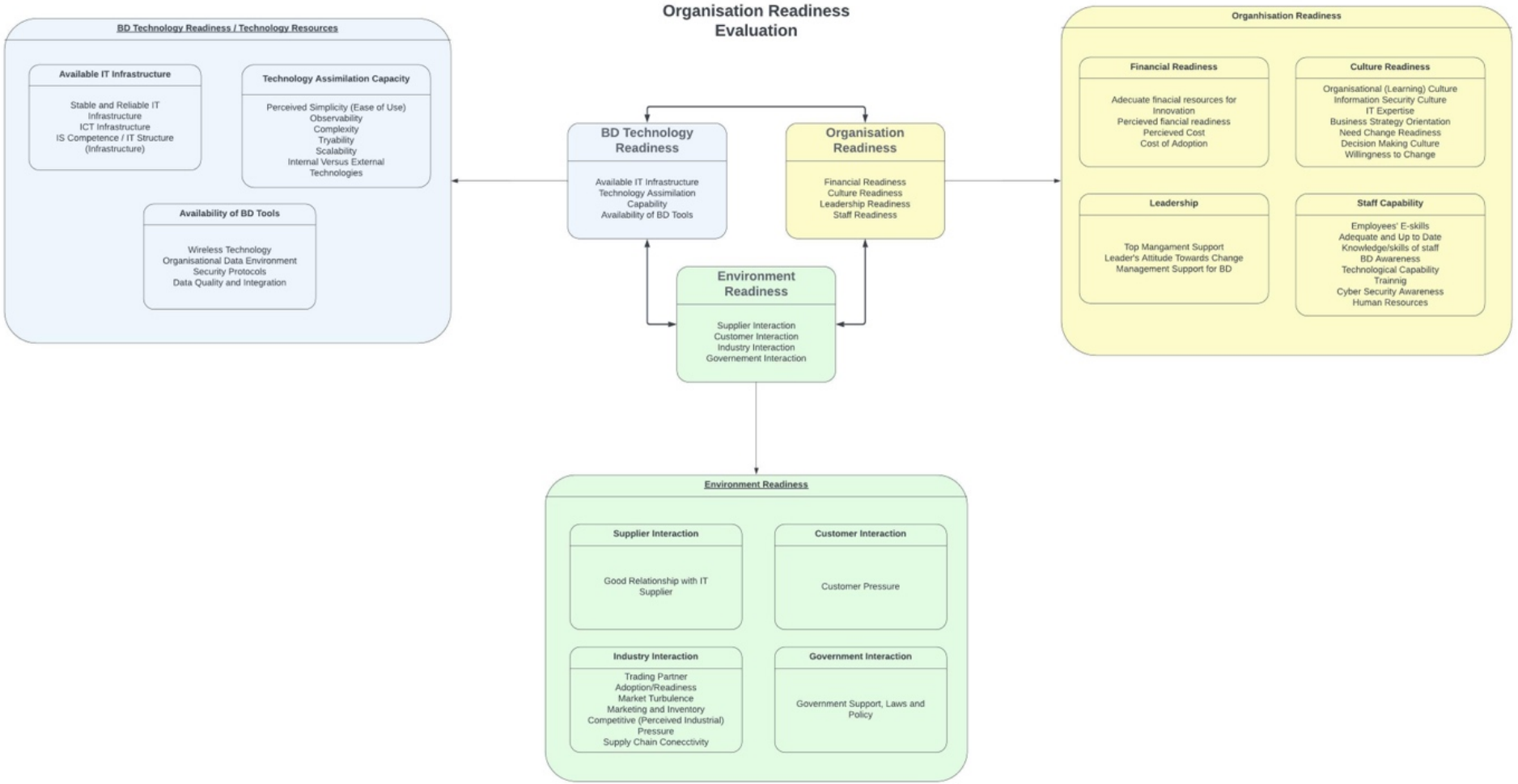


Figure 9.2: Organisational readiness assessment tool evaluation criteria

9.3.1 Technology readiness

The technological context involves the organisation's technological setting. According to Baker (2011) and Tornatzky et al. (1990), it should consider all relevant technologies including the requirements of the existing technologies and innovations not yet adopted in the organisation. At the same time, the measurement of technology readiness refers to the capability of the organisation to make optimum use of technical infrastructure (Durga & Singla, 2019). Moreover, implementing BD analytics requires organisations to have a structure that allows them to handle and process massive volumes of data in real time (Kalema & Mokgadi, 2017). From the combination of these concepts and requirements, the following elements were identified as technology readiness measurement units.

The available IT infrastructure describes the necessary components to support the BD process. Both studies, Kaisler et al. (2013) and Kalema and Mokgadi (2017), agree that infrastructure plays an essential role in the preparation of the adoption of new technologies and more so in the case of BD since organisations must be able to admit and integrate diverse forms of data from different sources.

Technology assimilation capability refers to the capacity of the organisation to assimilate technology through different processes and levels (de Mattos & Laurindo, 2017; Purvis et al., 2001). Furthermore, it was found in this study that the technology assimilation capability represents a critical success factor in a construction organisation adopting BD successfully. The participants responded with the following when asked about the determining factors for the adoption of BD in the industry:

> *"[…] that if is a program is an easy-to-use program or if is a platform or a way of doing or programming that is something that a construction company sees as necessary and productive and attractive". I2*

Following the same lines, interviewee I20 stated:

> *"[…} It needs to be easy to access and understand, or to have clear who is directed to if in the future we will need to hire big data professionals where and how are those professionals going to be trained […]". I20*

The availability of BD tools discusses the specific infrastructure needed to support the BD processes. Authors such as Nasrollahi and Ramezani (2020), Mneney and Van

Belle, (2016), Olszak and Mach-Król (2018), and Baig et al. (2019) recognise the role of the availability of technological tools as an essential part of the adoption process. Moreover, this element was also identified as a determining factor in the adoption of BD in the construction industry during the primary data collection phase, as demonstrated by the following statements:

> *"[…] maybe availability of technological tools, not everyone has the same access, I mean, not everyone has even regular technological tools, not everyone in the company has a computer, not everyone has a company cell phone in some cases". I3*

Interviewee I18 also added:

> *"[…] I would say […] access to whatever tool that we are going to use to analyse our data should be accessible and easy to use, and it should produce a change to better when applied, for me, is the most important thing, otherwise, I wouldn't bother investing in it". I18*

The measurement units were selected for the readiness tool due to the importance observed in the literature and the interviews conducted with industry professionals as part of this study. The following table (Table 9.2) presents the questionnaire related to the technology readiness evaluation.

Table 9.2: Technology readiness assessment questionnaire

BD Technology Readiness/Technology Resources						
Statements		**Score**				
		1	**2**	**3**	**4**	**5**
1	**Available BD IT Infrastructure:**					
1.1	This organisation has a stable and reliable IT infrastructure (e.g., hardware, software, networking components, an operating system (OS), and data storage).					
1.2	This organisation has a reliable Information and Communication Technology Infrastructure (e.g., digital telephone network, mobile phones, internet capability, internet servers and fixed broadband, and others).					
1.3	This organisation has Intelligent System Competence.					
2	**Organisation's BD Technology Assimilation Capacity:**					

2.1	This organisation has an adequate understanding of BD.					
2.2	This organisation has adequate protocols to improve BD observability (i.e., the ability to collect data about the program execution, the internal states of the modules, and the communication between components).					
2.3	This organisation is able to embed BD at all levels.					
2.4	This organisation has adequate protocols to understand BD's complexity and trialability (i.e., how easily potential adopters can explore BD).					
2.5	This organisation has adequate protocols to help them understand BD scalability (i.e., the ability of a hardware/software parallel system to exploit increasing computing resources effectively in the analysis of (very) large datasets).					
3	**Availability of BD Tools:**					
3.1	This organisation has advanced wireless technology to capture and transmit data.					
3.2	This organisation has a healthy data environment (e.g., a mechanism to protect data privacy and anonymity).					
3.3	This organisation has adequate security protocols for data management.					
3.4	This organisation has an adequate infrastructure for data integration and quality.					

The technology readiness factor looks into the organisation's infrastructure, if it is able to support the BD processes and if the organisation can handle other essential requirements such as complexity, scalability and security (Srinavin, Kusonkhum et al. 2021). The overall technological readiness score was assessed by calculating the total score assigned to each statement as follows:

- 60 – 48 Organisation member strongly feels that they are ready to tackle BD's technological challenges.
- 47 – 35 Organisation member fairly feels that they are ready to tackle BD's technological challenges.
- 34 – 22 Organisation member feels, to a certain extent, that they are ready to tackle BD's technological challenges.
- < 21 Organisation member does not feel that they are ready to tackle BD's technological challenges.

9.3.2 Organisational readiness

Organisational context refers to the organisation's internal features (Tornatzky et al., 1990). For this section of the tool, the elements to be considered are financial capability, culture, leadership, and the capability of its workforce. According to the studies by Srinavin et al. (2021) and Baker (2011), another essential element to be contemplated in the adoption of innovations and specifically BD is the firm's size. This has been reflected in this study as one of the sample-defining characteristics as highlighted in Chapter 4.

Organisational readiness denotes the relationship between the inner characteristics of the company, such as the processes, systems, performance, and people, all of which are essential when successfully implementing any innovation process (Greeff & Ghoshal, 2004). Furthermore, measuring the organisation's readiness to adopt BD implies analysing its cultural habits as well as the way that they approach problem-solving. This will allow for the addressing of any shortcomings before implementation (Sebastian-Coleman, 2013). Consequently, the elements selected as the measuring units of the tool in the organisational context seek to assess the internal characteristics of the organisation.

Financial capability or readiness contemplates the organisation's availability regarding financial resources to adopt and maintain BD, and the awareness of the costs and preparedness to face them (Kalema & Mokgadi, 2017). This element is of great influence in the BD adoption process because the technology deals with a continuous and exponential increase in its datasets which translates into requiring more upgrades, tools, and resources to function. The findings of this study agree with this as expressed by the interviewees in the following statements:

> *"[…] that the cost becomes accessible for instance and that it is something achievable, for us as a company, it doesn't matter if this technology can solve all of the challenges that we face if we can't afford it […] that becomes not only the cost but the technology and all that is required to adopt it, that becomes easy to access, that becomes within reach of the people". I2*

In the same way, I16 also expressed the following:

> *"[…] knowledge and understanding, is how I said before, in the beginning, those are the main factors, then will follow things like accessibility and cost for*

this in specific there must be awareness of how much the organisation must invest not only to put the technology in place but also to maintained over time". I16

Cultural readiness relates to the organisation's ability to distribute resources, stimulate its employees, and how it assesses its performance. Kalema and Mokgadi (2017) argued that a culture that allows the integration of its employees' different areas of experience to solve problems will find it necessary to adopt BD and any other innovation. Alam (2016) proposed a series of steps necessary to build an organisational BD culture. These steps include the:

- Clarity of the goal that needs to be attained
- Involvement of key people in BD decision-making
- Promotion of a data-driven mindset
- Anticipation and being ready for objections
- Being in a position to address emotions
- Educate the people involved in the Big Data projects and be ready to take action

In the same way, this element was highlighted during this study. The interviewed participants identified a technologically-driven organisation culture as one critical factor for BD adoption, as can be seen in the following statements:

"[…] I think […] the adoption and the culture of the company or industry, it has to be a drive for competitiveness for the company, and everyone has to be clear on what or how this technology is going to be put to use […]". I7

Interviewee I14 also added:

"This will be really similar to what I answered before, and is that people and by people, I mean, companies need to know what it is and how they can benefit from it. And that they take this as part of their everyday process as part of the culture; otherwise, you can end up investing in something that no one uses". I14

The next measurement unit is leadership. This refers to the support the organisations receive from the top management when implementing change. Organisational leadership studies how leaders affect their organisation's performance through individual and organisational influence. Thus, they are considered to be agents of change (Bratton, 2020; House et al., 1997). Various sources such as Nasrollahi and

Ramezani, (2020), Nguyen and Petersen (2017) and Sun et al. (2018) considered this element to be essential when adopting new technologies like BD in an organisation. Leaders are in charge of actions such as staff recruitment and training, appropriate budgets, and helping align the organisation and its IT strategies. The findings of this study are also in agreement with identifying leadership as a high-influence factor in the adoption of BD in construction organisations and the industry, as confirmed by the following statements:

> *"Directive will, I think the decisions management takes must be aligned with what the company is trying to achieve. If is adopting BD or any new technology, they should lead and take the necessary steps to make that happen". I9*

Interviewee I15 also stated:

> *"[the adoption of a new technology] well, it depends on everything, basically, cost, return of the investment, personal training, and is up to management to make these decisions that will benefit or drawback the organisation's ability to adopt the technology, so they need not only to be on board but to lead in any change we want to implement". I15*

Staff capability is the last measurement unit for organisational readiness. It discusses the knowledge and skills that the workforce should have in order to adopt BD. Kalema and Mokgadi (2017) argue that organisations looking to implement BD require capable employees with the necessary skills to engage with the technology, thus making this characteristic influential when it comes to organisational readiness. Moreover, in its analysis, this study found that the staff need to have certain skills for the organisation to implement technological development, as explained by the following statements from Interviewees I4 and I20.

> *"[…] education on the subject, I believe workers need to know what it is, how it works and what are the benefits as well. Also, there must be a plan beforehand to review the skills they need to work with this technology and or how they can obtain them in case they don't have it". I4*

Also,

> *"That it becomes popular and whatever form it may come whether it'll be a program or tool or software it needs to be easy to access and understand for the company staff, or to have clear who is directed to if in the future we will need*

to hire big data professionals where are those professionals going to be trained […]". I20

These measurement units were selected for the readiness tool due to the significance established during the data collection phase of this study and the literature. The following table (Table 9.3) presents the evaluation questionnaire related to organisational readiness.

Table 9.3: Organisational readiness assessment questionnaire

Organisational Readiness						
Statements		**Score**				
		1	**2**	**3**	**4**	**5**
1	**Financial Capability**					
1.1	This organisation is able to allocate adequate financial resources to adopt/maintain the BD infrastructure.					
1.2	This organisation has confidence in their financial readiness to adopt BD.					
1.3	This organisation believes that the perceived cost of BD adoption is affordable.					
1.4	This organisation has done the research and has the resources to adopt BD.					
2	**Culture Readiness**					
2.1	This organisation has a digitally driven organisational culture.					
2.2	This organisation has a well-established security culture.					
2.3	This organisation has adequate IT expertise.					
2.4	This organisation has a digital innovation business strategy orientation.					
2.5	This organisation has an adequate need for change readiness.					
2.6	This organisation has an efficient decision-making culture.					
2.7	This organisation has a low/non-existent resistance to change.					
3	**Leadership**					
3.1	The top management supports innovation initiatives.					
3.2	Leaders have a positive attitude towards change.					

3.3	Management supports and encourages the use of BD.					
4	**Staff Capability**					
4.1	The staff have advanced e-skills.					
4.2	The staff has adequate and up-to-date BD knowledge/skills.					
4.3	The staff clearly understand the benefits of using BD in construction projects.					
4.4	Staff have the technological capability to contribute to the BD environment (e.g., data management protocols).					
4.5	Staff is provided with training where they can develop familiarity with BD tools.					
4.6	Staff is aware of cyber threats and how to deal with them.					
4.7	Human resources promote learning and iterative improvement as well as risk-taking.					

The organisational readiness section measures the organisation's internal capability to adopt BD from finance to culture and other resources. It assesses the elements that must be present to achieve successful implementation. The overall organisational score was determined by calculating the total score assigned to each statement as follows:

- 105 – 84 Organisation member strongly feels that they have the necessary skills and knowledge to execute the tasks and activities associated with BD implementation.
- 83 – 62 Organisation member fairly feels that they have the necessary skills and knowledge to execute the tasks and activities associated with BD implementation.
- 61 – 40 Organisation member feels, to a certain extent, that they have the necessary skills and knowledge to execute the tasks and activities associated with BD implementation.
- < 39 Organisation member feels that they don't have the necessary skills and knowledge to execute the tasks and activities associated with BD implementation.

9.3.3 Environmental readiness

According to Tornatzky et al. (1990), the environmental context refers to the external stakeholders' influence on the organisation. This context involves how these factors stimulate innovations (Baker, 2011). Environmental readiness refers to the organisation's interaction with its external influencers such as suppliers, customers, industry and the government, all of which will positively or negatively impact the organisation's ability to embrace innovations (Srinavin et al., 2021). The definitions of these measurement units are presented below.

Supplier interaction looks into the organisation's relationship with its vendors. Kalema and Mokgadi (2017) established that organisations generally need constant support from their suppliers and even more so in the case of BD, since these provide essential procedures and guidance for adopting applications and analytical tools. Moreover, Mitrega et al. (2017) explained that a good organisation-supplier relationship amplifies innovation since the latter constitutes an important source of resources such as technology, skills and knowledge.

The second measurement unit is customer interaction which assesses the organisation-client relationship. In other industries, the interaction between an organisation and its customers aims to understand their needs to offer a better product or service. It comes from many different means, such as social media, mobile, stores, e-commerce, etc. (Kaisler et al., 2013). In construction however, the relationship aims to create a partnership between the organisation and its clients. The latter continue to use the former's products and services while identifying the sources of costly problems (Designing Buildings, 2022). Kalema and Mokgadi (2017) demonstrated that customer demands influence BD readiness since, in general, people have become more IT knowledgeable and tend to do more of their work online, including requests and submissions to organisations which, in turn, need to provide faster answers to these customer queries.

The third measurement unit is industry interaction. This factor looks into the relationship between the organisation and industry, how the latter can impact the former, and how it can influence the adoption of BD in an organisation by offering competition, which can power innovation (OECD/Eurostat, 2019). Kalema & Mokgadi (2017) believe that, on the contrary, BD can help organisations achieve

competitiveness by analysing the actions of their competitors in the market. Sun et al. (2018) also adds that BD can help combat the pressure from competitors.

Finally, the fourth measurement unit is government interaction which assesses the effect that government regulation and policies exert on the organisation and its readiness for adopting BD. Government support programmes, public policies, and regulations are considered by OECD/Eurostat (2019) as the drivers of innovation. Sun et al. (2018) agrees with this by reflecting that the support provided by governmental agencies can encourage organisations to adopt BD. Furthermore, government policies can be considered to be among the drivers for adoption intention (Lai et al. 2018).

The analysis performed as part of this study also yielded similar results; the participants identified government regulation and support as a critical success factor of BD adoption, as expressed in the following statement:

> *"Well, the last would be for it to be part of the norms, but that is a utopia really. We don't have, maybe, to reach that point, but that also would boost the implementation in a country". I2*

Interviewee I11 also expressed:

> *It would be that it […] it needs to count with government support, so companies feel motivated to change their usual decision-making tools to this new technology". I11*

As with the previous sections, the units of measurement for environmental readiness were selected based on their recognition in the literature and the primary data analysis. In the same way, the following table (Table 9.4), presents the questionnaire related to the organisational readiness evaluation.

Table 9.4: Environment readiness assessment questionnaire

Environment Readiness						
Statements		**Score**				
		1	**2**	**3**	**4**	**5**
1	**Supplier Interaction**					
1.1	This organisation has a good relationship with IT suppliers to facilitate BD innovations.					

1.2	This organisation keeps up to date with new digital developments.					
1.3	This organisation seeks support from IT experts to understand how to apply any new tools and software best.					
2	**Customer Interaction**					
2.1	This organisation responds to customer pressure.					
2.2	This organisation offers digitally innovative solutions to customers.					
2.3	This organisation uses technology to improve the information flow with customers.					
3	**Industry Interaction**					
3.1	This organisation understands and is prepared to deal with market turbulence.					
3.2	This organisation has an adequate marketing and inventory management system.					
3.3	This organisation recognises competitive pressure as a drive for BD adoption.					
3.4	This organisation has adequate (digitalised) supply chain connectivity (e.g., orders, tracking, and inventory levels).					
4	**Government Interaction**					
4.1	This organisation responds to innovative government policies.					
4.2	This organisation engages with government bodies to support BD adoption.					
4.3	This organisation engages and interacts with government agencies to improve the regulation of new technologies.					

The environment readiness section measures the organisation's response to the external elements that influence its capability to adopt BD. The interactions between the organisation and its suppliers, customers, industry, and government were defined as a critical success factor for BD adoption in both the primary data collection and literature. The overall organisational score was determined by calculating the total score assigned to each statement as follows:

- 65 -52 Organisation member strongly feels that the organisation's interaction with its external environment supports the adoption of BD.
- 51 – 38 Organisation member fairly feels that the organisation's interaction with its external environment supports the adoption of BD.
- 37 – 24 Organisation member feels, to a certain extent, that the organisation's interaction with its external environment supports the adoption of BD.
- < 23 Organisation member does not feel that the organisation's interaction with its external environment supports the adoption of BD.

9.4 Organisation's Global Readiness Score

To assess an organisation's Big Data readiness, a representative sample of said organisation has to complete the questionnaire and respond to the statements in each context. After all of the questions have been answered, the final score on the employees' perception of their organisation's readiness to adopt Big Data is obtained by adding the score of all three sections together. The overall score for BD readiness can be classified as follows:

- **230 – 184** The organisation is as ready as possible to adopt Big Data.
- **183 – 137** The organisation is very ready to adopt Big Data.
- **136 – 90** The organisation is partially ready to adopt Big Data.
- **< 89** The organisation is not prepared to adopt Big Data.

9.5 Validation of the Organisation's Readiness Assessment Tool for BD Adoption

The evaluation for the organisation's readiness assessment tool for BD adoption follows the process described in section 4.7 According to Phelps (2011), "The validation process involves gathering evidence to evaluate the soundness of these proposed interpretations for their intended use."

The process consisted of a First stage where the outcomes of the research were presented as well as the readiness tool and framework. The participants then were given some time to examinate and reflect of the tool and invited for a follow up interview where they submitted their feedback. The developed tool was validated by seven professionals in the construction industry. The participants were from four different countries: Canada, USA, UK and the Dominican Republic.

The selection was made based on their knowledge of Big Data and previous experience developing readiness tools. A total of five questions were developed to assess the tool's level of understanding, level of termination, logic flow, and usefulness, as well as a final question allowing for any comments from the participants regarding necessary improvements. The feedback obtained from the evaluation process will be discussed in the following subsections.

1. **Level of understanding**

The average response to this question was that the tool is comprehensive and would provide a clear picture of where the organisation stands in terms of readiness to adopt big data, but also of what needs to be improved to reach the stage where they can achieve a positive outcome of the adoption process. Participants also agreed that the readiness tool has a clear and easy to understand structure.

2. **Level of termination of the tool**

The participants consider all sections (and content within) to be relevant to measuring the readiness of organisations to implement Big Data in the context of the TOE framework on which is based. However, some other elements such as economic factor should have also been considered. Although, at the same time, they recognise this would restrict the way in which the tool can be applied, therefore, the recommendation is to include some form of general acknowledgement of the financial implications of the process.

3. **Logic flow of the proposed readiness tool**

The participants widely agreed that the readiness tool possesses a good logical flow of processes. Concepts and elements are well connected and represent an appropriate process to follow when assessing an organisations readiness to adopt Big Data.

4. **Usefulness of the tool**

All participants consider this tool to be useful to some extent. Some considerations were brough up and discussed below. However, it was also positively highlighted the capability of providing not only the level of readiness but the information on the missing elements to achieve full readiness for the adoption of Big Data through the different levels of assessment available within the tool. Finally, the tool has been considered “a good first step” and accurate for an organisation looking to start their journey for implementation.

5. **Comments and suggestions on areas that need improvement.**

Some suggestions were made by the participants to improve the tool:

- To include within the culture section some elements related to data security and risk mitigation which must be part of the organisation protocol.
- To have the tool also available in different languages in order to reach a wider audience, especially in Spanish since the tool was developed parting from research performed in the Dominican Republic.

6. **Changes and final comments on the readiness tool**

The feedback received during the validation process has been incorporated into the framework and development in other languages will be considered for future research.

9.6 Summary

This chapter discusses the development of a tool to assess an organisation’s readiness to adopt BD. The tool was based on a combination of the study's findings and the literature review. The readiness assessment tool is aimed at construction organisations that want to benefit from BD adoption. It will assist by assessing their readiness to adopt the technology and highlight their weaknesses, thus providing a roadmap for implementation.

The assessment tool is based on the TOE framework developed by Tornatzky, Fleischer and Chakrabarti in 1990. It covers the three main areas involved in technological innovations: technology, organisation, and the environment. As such, the assessment tool is divided into three sections, technology, organisation, and environmental readiness, which are evaluated individually through units of measure

before providing a global score for the organisation. Moreover, the tool will assist the organisation's decision-makers in understanding BD-related concepts, requirements, and areas of improvement for a successful implementation. Overall, the participants of the evaluation process considered the tool to be useful for an initial implementation, especially since will allow organisations to understand what needs to be considered and how far/close they are to the implementation, to be followed by creating specific plans for the company in a particular way.

The tool was evaluated by experienced professionals from different industries and countries. In some cases, the professionals suggested areas for improvement that have been considered for further research.

CHAPTER 10. INTEGRATED FRAMEWORK FOR BIG DATA ADOPTION IN THE CONSTRUCTION INDUSTRY

10.1 Introduction

This chapter explains the integrated framework for adopting BD in the construction industry. The chapter addresses Research Objective Number Seven (RO7): "To develop and validate a framework for the implementation of BD in the construction industry."

The proposed framework was developed based on the findings of the previous chapters. The framework provides a better understanding of the elements involved in adopting BD in an organisation. This framework aims to assist construction organisations that seek to adopt Big Data technology.

This chapter is structured as follows. Section 10.2 explains the rationale behind the proposed framework, Section 10.3 defines the structure and functionalities of the developed framework, and Section 10.4 describes the process for validating the proposed framework. Finally, Section 10.5 presents a summary of this chapter.

10.2 Rationale for an Integrated Framework for Adopting BD in the Construction Industry

The construction industry has been traditionally known as a "high consumption and high pollution" industry (Zhang et al., 2021). The increased awareness of the conscious use of resources has caused society to pressure the industry to mitigate its impacts. Nowadays, countries like China and Pakistan are encouraging the adoption of technological innovations to meet society's sustainable requirements across all industries (Zhang et al., 2021; Shahzad et al., 2022). However, the intrinsic resistance to change in the construction industry adds another level of difficulty to adopting this type of initiative (Ngo et al., 2020; Silverio-Fernandez et al., 2019; Srinavin et al., 2021). Moreover, implementing innovations is a complex process and requires a high level of research and development that is beyond the capabilities of many organisations and industries (Shahzad et al., 2022; Moullin et al., 2015).

When looking to implement technological innovation, it is common to focus on the most critical areas, such as drivers and barriers (Markard & Truffer 2008). Therefore,

frameworks are the tool of choice for this task. According to Moullin et al. (2020) and Moullin et al. (2015), frameworks are a tool used to explain the implementation process based on the essential elements involved. It provides a foundation upon which implementation can be achieved. Moullin et al. (2020) also added that an implementation framework is essential for an implementation effort since it helps to identify the determinants or elements that will impact the process through the different phases and levels involved.

10.2.1 The need for a structured framework

An urgent need has been established in this study to understand the elements that influence the adoption of BD, the value that its implementation would create for the construction industry, and how the adoption process would benefit from a guide where the active components and the relationship between them are represented. Moreover, this framework would allow stakeholders to better understand BD technology and how its adoption would impact their organisations. Furthermore, the opinion of the interviewees was also considered to justify the need for a strategic framework. The participants in this investigation's qualitative data collection process showed an interest in obtaining and using a guideline for adopting BD in their organisations.

During the data collection, the interviewees were asked about the need for a set of guidelines or framework for adopting BD in the construction industry of the Dominican Republic.

Overall, 81% of interviewees expressed the need for this guidance with statements such as:

> *"Definitively would speed the implementation process, since something available to everyone and explicative in nature would mean that all the industry would have some standardised level of knowledge on the subject, allowing everyone to develop the area that they think is more needed in their organisations, also, to have some type of government endorsement of this document would help to create confidence in the new technology and facilitate its adoption". I13*

In the same way, Interviewees I6 and I20 expressed the following:

> *"[…] it could impulse the implementation of BD and any other technology that requires a change in the culture of a construction company". I6*

"[…] I think that it would be a good first step in the right direction, more even if that document could be used to teach, as I said, the future professionals that will work with this technology. I think this is very important because if this results in something game-changing, you will have a big demand of people that knows how it works and very few to satisfy that demand". I20

There is a consensus that the sector would greatly benefit from a framework for BD adoption. Both the literature and this study agree that this step would positively impact the industry's chances of adopting the technology.

10.2.2 Framework beneficiaries

The proposed integrated framework is directed toward organisations that wish to adopt BD in the construction industry. This framework is aimed at assisting decision-makers in understanding the concept of BD and its implementation process. In more depth, the framework improves the organisation's understanding of the following factors:

- The role of the drivers (input) for BD adoption.
- The inter-relationships among the different factors and the actions to be taken (process) to embed the technology in the organisation.
- Successful BD adoption's impact on the organisation's performance (output).
- The impact on the organisation's competitiveness (outcome).

Overall, the framework will benefit all construction industry stakeholders who seek to understand the factors involved in adopting BD and smart technologies by enabling them to better understand the relationships between each of these elements and their readiness to tackle its implementation. This framework will help them to elaborate on an action plan for adopting BD in organisations, as well as understanding what challenges it will need to overcome to reap the benefits of implementation.

10.3 Proposed Integrated Framework for Implementing Big Data in the Construction Sector

The proposed framework, as shown in Figure 10.1, was designed based on the results of the literature review and the analysis of the interviews with professional decision-makers from the Dominican Republic's construction industry. The framework is comprised of four main stages: inputs, processes, outputs, and outcomes. The framework was built based on a combination of frameworks and theories such as

Tornatzky and Fleischer's technology-organisation-environment (TOE) framework (1990) and organisational change management.

The inputs stage represents the organisation's internal and external forces that drive decision-makers to adopt BD as an agent for change. Once the drivers are identified and evaluated, the organisation is able to formulate and implement suitable actions (processes) to adopt BD. These actions will lead to outputs in the form of better and more sustainable performance. The improvement in economic, social and environmental performance will be reflected in the organisation's long-term performance (outcomes). A continual feedback loop is also included to ensure information flow between stages, allowing decision-makers to adjust their implementation strategies.

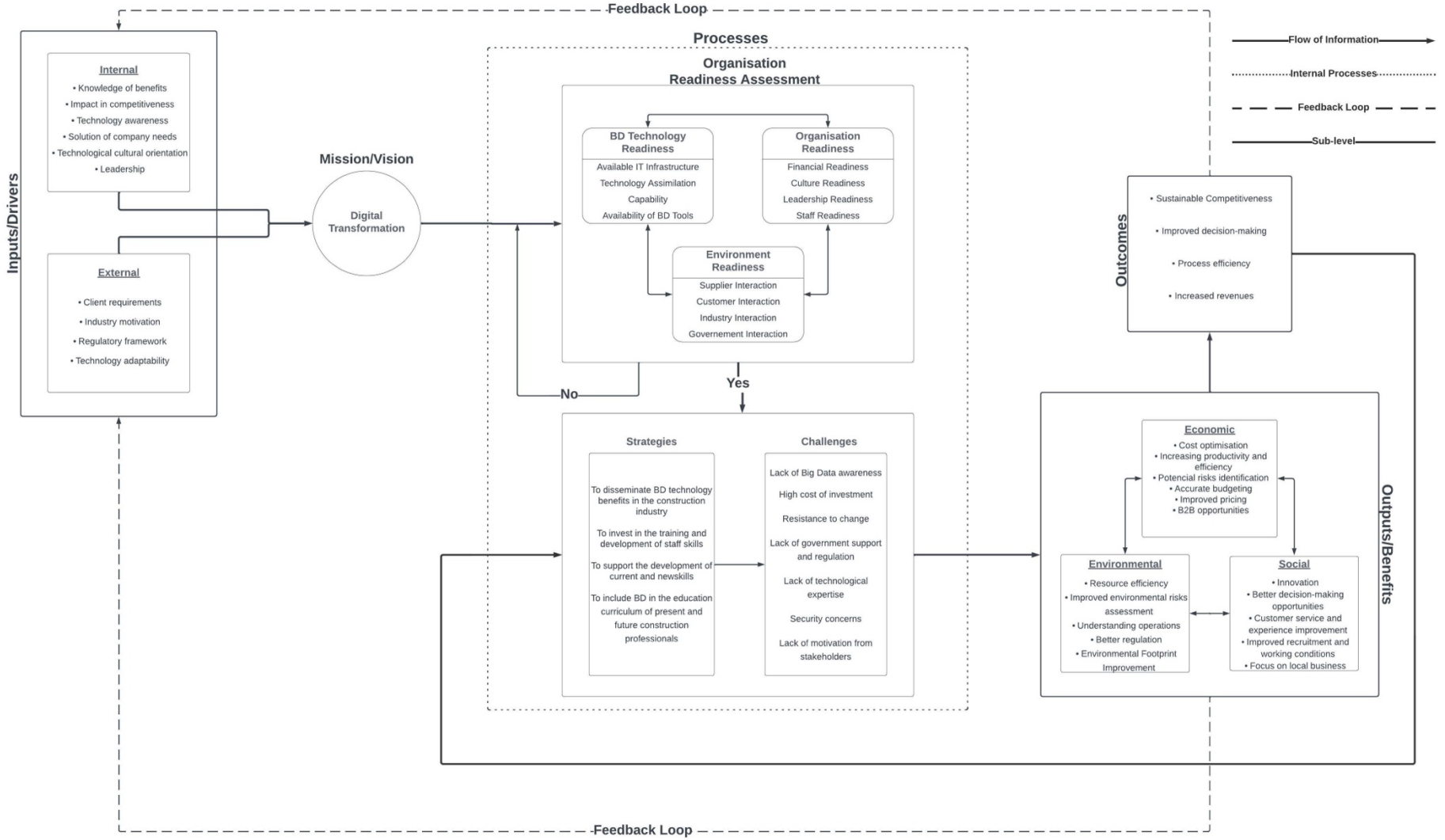


Figure 10.1: Integrated framework for adopting Big Data in construction organisations.

10.3.1 Inputs

The inputs section of the framework contains the drivers for adopting BD in the construction industry of the Dominican Republic. These drivers represent the forces for change within an organisation and have been classified as either internal or external. On the one hand, internal drivers are the forces originating from inside the organisation, such as the knowledge of BD benefits to the organisation, the impact on competitiveness, technology awareness, the solution to the company's needs, and technological cultural orientation. On the other hand, external drivers or forces exert pressure on the organisation such as client requirements, industry motivation, the regulatory framework, and technology change adaptability. Organisations must understand these drivers to adopt BD properly since they will define the organisation's internal capability and response to external pressure.

The proposed framework section depicts the relationship between the drivers as well as the mission and vision as shown below (Figure 10.2). Nine drivers were identified as crucial for BD adoption in construction organisations. For a more in-depth review, see Chapter 6.

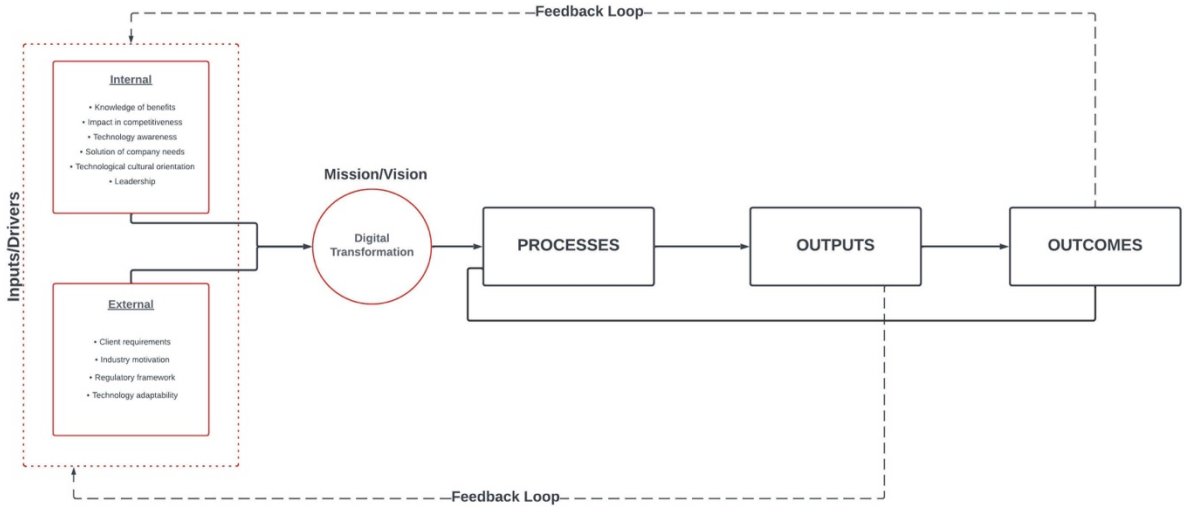


Figure 10.2: Inputs section of the proposed integrated framework

The internal forces are the organisational factors pushing for BD adoption in construction organisations.

- **Knowledge of the benefits:** A strong motivation for organisations to implement new technology like BD is to know what benefits or advantages such an adoption would provide the organisations. This knowledge of the benefits would

also help them to overcome the resistance to change that is characteristic of the industry.

- **Impact on competitiveness:** A leading factor for change within organisations is the impact of said change on competitiveness. This relates to the ability to deliver better value over other companies that offer similar services.
- **Technology awareness** refers to the ability to comprehend and recognise the value that new technology can provide the business. It also involves keeping up to date with the evolution of the same technology.
- **Solution to company's needs:** Satisfying the company needs is one determining factor when implementing BD. Company needs are the goals or objectives the business must achieve in order to function, generate profit, or deliver the company's mission.
- **Organisation's technology-driven culture:** The organisation's culture defines the organisations prevailing beliefs, behaviours, values, and conventions (Warner Burke & Litwin, 1992). A technology-driven culture pushes the organisation to stay at the forefront of new technologies or technological orientation in terms of BD.

Additionally, the analysis of the literature identified one more essential element as a driver of change within an organisation. This is:

- **Leadership:** This considers the influence that leaders have in their organisations and in relation to the successful implementation of BD since a company with a leadership that inclined towards innovation is more likely to invest and work towards adopting new technologies.

External drivers are the environmental factors pressuring the construction organisation to adopt BD.

- **Client requirements** are elements that can force change within companies. In some cases, they may require the implementation of methods or technologies that are beneficial for the delivery of the project,
- **Industry Motivation:** Industry motivation is critical due to its ability to compel companies to adopt certain practices such as BD or BIM. Once a company achieves added value because of the implementation of a new technology, the industry takes on the responsibility to spread and promote this practice, awaiting similar results (Madanayake & Egbu, 2019).

- **Regulatory framework** refers to any official policy or regulation approved by the government in order to normalise an activity. In some cases, it can issue a regulation requiring the adoption of practice or technology that can satisfy some need or the ability to provide benefits that are aligned with the objectives of the institution such as data management or transparency.
- **Technology change adaptability** refers to the technology's ability to integrate into a company, how easy it is to comprehend, its compatibility with existing programs, and the ease with which the staff can understand and master its use. The participants identified this factor as a key driver since this is how companies can fully implement the technology and take advantage of its potential.
- **Mission and Vision:** An organisation's mission expresses the organisation's purpose and primary objectives, as well as representing the current base upon which all activities are built (Warner Burke & Litwin 1992). In contrast, the organisation's vision symbolises what it wants to achieve in the future. These two are often put together since they represent the organisation's journey to the future. An organisation's mission is tightly related to its strategies and objectives and for organisations to be able to adopt BD, they must embrace digital transformation (DT) as their core strategy. Digital transformation is the process of creating or modifying the business processes through the use of digital technologies (Fernandez-Vidal et al., 2022). Construction companies hoping to adopt BD must embed this concept as part of their culture since it will allow the migration from analogue to digital in all areas of the organisation.

Finally, every organisation within the Dominican Republic's construction industry operates in a specific context that impacts how said company chooses its strategies and decisions. Therefore, the key drivers may fluctuate between organisations.

10.3.2 Processes

After studying and assessing the forces driving the organisation toward BD adoption, decision-makers are able to consider and develop the processes to achieve this goal. The second stage of the proposed framework is the "processes" which represents the process of transformation the organisation must undergo to reach the set goal of BD implementation in this case. This stage is composed of two sections, namely the organisation readiness assessment and organisational change management.

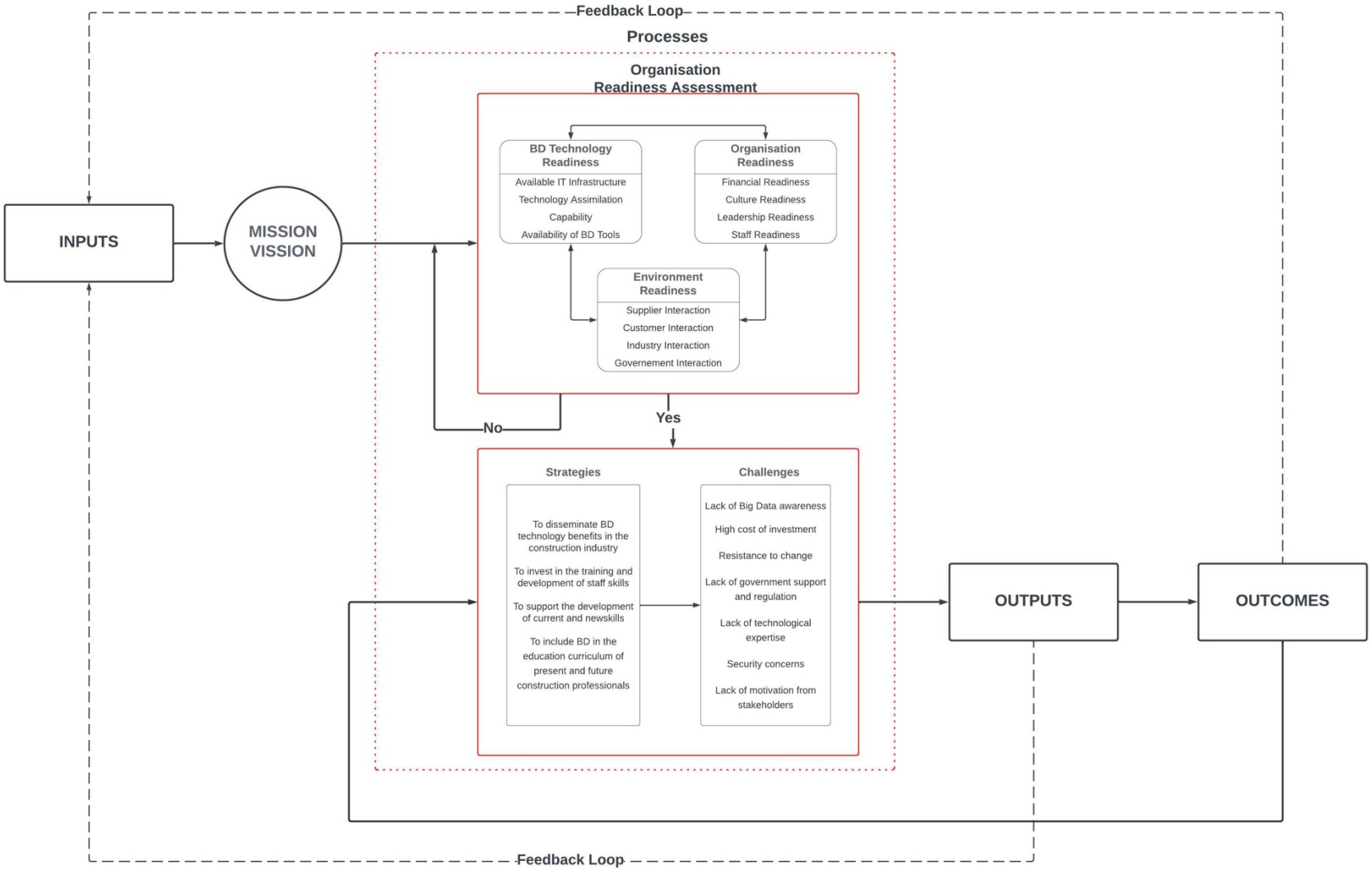


Figure 10.3: Process section of the proposed framework

- **Organisation's readiness assessment:** The readiness assessment tool presented in the previous chapter (Chapter 9) is embedded as part of this framework. The readiness tool is based on Tornatzky and Fleischer's technology-organisation-environment (TOE) framework to evaluate the different factors influencing organisational decision-making (Baker, 2011; Tornatzky et al., 1990). Assessing readiness is a process through which the ability of an organisation to adopt a change can be determined since it provides an opportunity to address the issues that an organisation may face when implementing a new plan (HRSA, 2012). Moreover, Sarrakh (2021) explains that an early readiness assessment can represent a solution to the challenges prevailing in the construction industry such as a lack of awareness, high cost of investment, and resistance to change (for more in-depth information, see Chapter 9).
- Organisational change management is the process of adopting a change to achieve a goal. The term refers to altering a significant component of an organisation; this could be its culture, infrastructure, or internal processes (Stobierski, 2020). This section contemplates three subsections as part of the organisational change management process: strategies, challenges, and critical success factors, all of which have been defined in previous chapters.

10.3.3 Outputs

The third stage of this proposed framework is the outputs resulting from the BD adoption process. They represent the improvement in performance and intermediate benefits of BD adoption. These benefits have been explored in the literature. For a more in-depth review, see Chapter 2.

This framework stage can be used to measure the level of success of the BD adoption process. This stage is in the form of variables grouped into three main outputs, namely economic performance, environmental performance, and social performance, as shown (Figure 10.5).

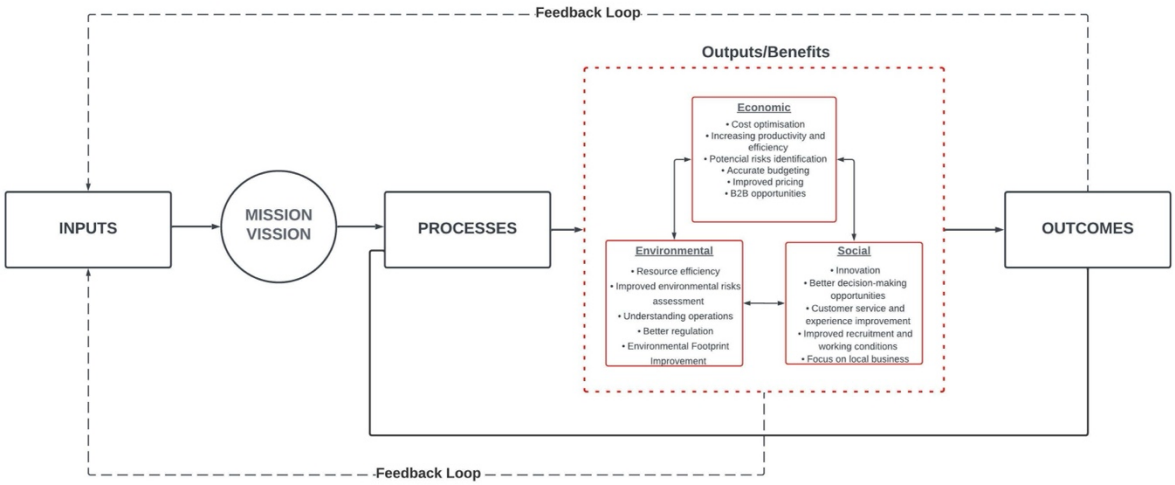


Figure 10.4: Outputs section of the proposed framework

- **Economic performance:** A successful BD adoption will positively impact the financial performance of construction organisations through new business-to-business opportunities, cost optimisation, increased productivity and efficiency, accurate budgeting, risk identification, and improved pricing. Improved economic performance will allow the organisation to invest in maintaining and developing the technology and thus increase the impact in all areas.
- **Environmental performance:** The high impact of construction activity on the environment calls for drastic mitigation measures. With the adoption of BD, construction organisations will be able to better understand operations, improve their environmental risk assessments, optimise the use of resources, improve the management processes, and reduce their environmental footprint.
- **Social Performance:** Supporting social development is one of the main goals of the construction activity. The organisations' social performance directly impacts the local communities. The adoption of BD in construction organisations can positively impact their social development by fostering innovation, creating opportunities for better decision-making, improving customer service and experience, and improving the recruitment and working conditions.

These sustainability performances must be monitored and evaluated periodically to ensure their alignment with the organisation’s mission and vision. A feedback loop has been included in the proposed framework, indicating that the outcome of this monitoring and evaluation must be included in the early stages of this iterative process.

10.3.4 Outcomes

The final stage of the proposed framework is the outcomes. This section represents the impact on the organisation's long-term performance based on the improved economic, environmental and social areas presented in the previous section. The portrayed outputs are the long-term impact of the increased performance due to BD adoption in construction organisations. This study identified four long-term benefits: sustainable competitiveness, improved decision-making, process efficiency, and increased revenues as shown (Figure 10.6). For more in-depth information, see Chapter 2.

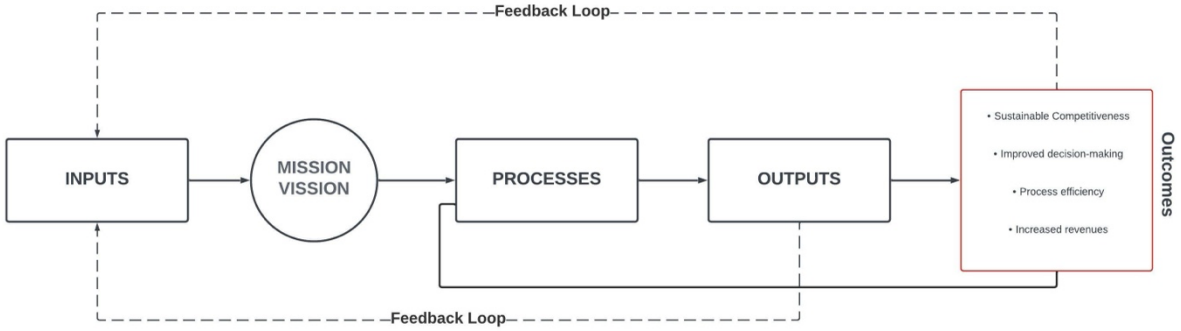


Figure 10.5: Outcomes section of the proposed framework

- **Sustainable competitiveness:** This refers to achieving growth considering all economic, environmental and social factors. BD is able to impact almost every aspect of sustainable development for which the UN has linked the technology to each of the 17 SDGs, some of which can be achieved through the construction industry (UN, 2022). In the specific case of construction organisations, the technology enables actions such as reducing waste and energy efficiency. At the same time, competitive advantage refers to the favourable position that an organisation achieves to perceive and obtain more profit than others. All other BD long-term benefits, such as optimised assets, improved productivity, and improved decision-making, work towards achieving a competitive advantage. The more efficient a process becomes, the more the organisation can focus on improving other areas. Moreover, consumer data can improve the organisation’s competitiveness by informing them of the need for better products and attracting more customers (Hagiu, 2021).
- **Improved decision-making:** Decision-making is critical for efficiently managing an organisation. This skill has been recognised as one of the general

effects of BD which can positively impact the construction sector by extracting insights from datasets, thus increasing the organisation's value-creation potential (Madanayake & Egbu, 2019; Ngo et al., 2020). Moreover, BD will enable the generation of feedback processes applicable to other technologies such as BIM (Garyaev & Garyaeva, 2019).

- **Process efficiency:** Effective business process management is critical for the organisation's development (deBara, 2019). Process efficiency has been identified as one of the effects of BD in the construction industry, which is vital when providing new products and services (Kupersmith et al. 2013).
- **Increased revenues** are among the goals behind the organisation's economic performance. BD promises an increase in the organisation's revenue powered by the insights extracted from analysing the information from previous projects and identifying errors (Raguseo, 2018; Caesarius & Hohenthal 2018; Pigni et al., 2016). The technology also helps increase the organisation's revenue by improving the quality of the products and services while reducing costs (Sydorenko, 2021). Furthermore, this has also been identified as a driver for adopting the technology (Raguseo, 2018; Maroufkhani et al., 2020).

As with the previous section, the identified outcomes must be monitored and evaluated, following the same process as before of feeding these results into the early stages of the process until the desired effects are achieved.

10.3.5 Proposed framework flow

The proposed framework contains elements that explain the sub-process flow between the components of the processes stage. This serves as a guide to enable the decision-makers to navigate and explore the actions they must take to achieve the ultimate goal of BD adoption. At first glance, the path to follow might seem linear but in reality, the sub-processes can be recurrent or happen simultaneously. Therefore, the approach to consulting this section is presented in the figure below (Figure 10.4).

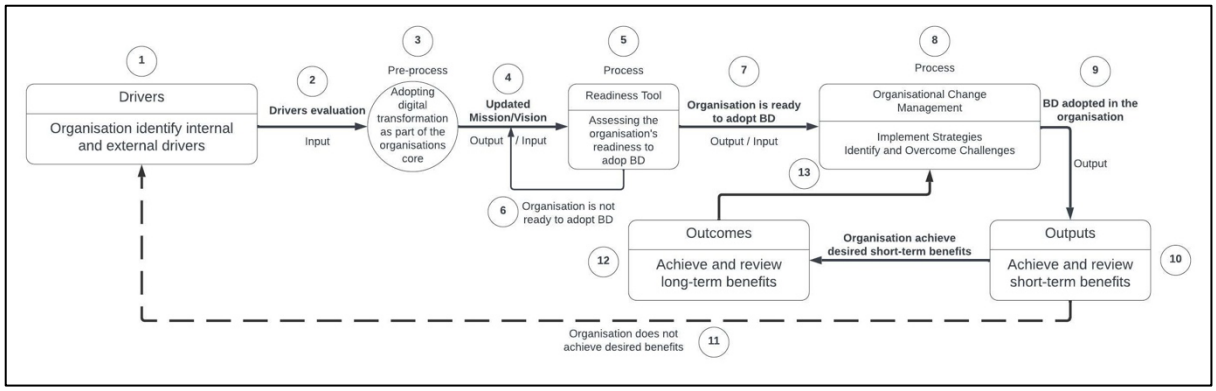


Figure 10.6: Proposed framework processes flow

1. The organisation identifies the internal and external drivers.
2. Evaluating the internal and external drivers in the organisation. These will serve as the input for adopting digital transformation as part of the organisation's mission and vision.
3. Adopting digital transformation as part of the organisation's mission and vision will allow for procedure migration from analogue to digital and prepare the organisation to adopt BD and other technologies.
4. Embedding DT into the organisation's culture will prepare the mindset to implement the necessary changes for BD adoption.
5. The readiness assessment process will allow for an understanding of the organisation's capability of adopting BD and what things are still needed to be able to achieve this goal.
6. If the assessment shows that the organisation is not ready to adopt BD, the drivers must be re-evaluated, the missing requirements must be addressed, and the process should start again until a different result is achieved.
7. The organisational change management process can begin when the assessment shows that the organisation is ready to make the change.
8. The organisational change management (OCM) process will guide decision-makers in adopting BD by identifying the strategies to be implemented and the challenges to be overcome to successfully implement the technology.
9. BD is successfully adopted in the organisation.
10. Organisation perceived and reviewed the short-term benefits.
11. If the organisation does not achieve the desired short-term benefits, it must refer to the identified drivers.

12. If the organisation achieves short-term benefits, it is on track to achieve long-term benefits.
13. If the organisation does not achieve the desired outcomes, it must refer back to the proposed strategies.

10.4 Framework Validation

The validation process for the developed framework followed the same method as the validation of the sustainability readiness tool explained in Section 4.7 Both validation processes were carried out at the same time, given the limited access to the participants. The questions were specifically designed to understand the interviewee's point of view about the framework and to allow its review and validation. The feedback obtained from this process will be discussed in the following subsections.

1. **Level of understanding.**

The framework was found to be easy to understand by the participants and in general by a specialised audience. Maybe not so much for a general audience such as government organisations. However, it was highlighted that the issue can be overcome by including the breakdown contained in the presentation. The participants found the framework to be very well structured and easy to follow.

2. **Level of termination of the framework.**

The participants consider the framework to cover the most relevant aspects that the construction industry. The inclusion of the readiness tool is appropriate because it will enable construction organisations to assess their readiness, and other organisations to understand what is needed to achieve a positive outcome in the adoption journey ensuring that the key players are ready for BD adoption.

3. **Logic flow of the proposed framework.**

Participants found the framework to follow a logical internal flow, helped by the section breakdown and guidelines provided. Also, the external connections help to understand the relationship between the different elements and processes.

4. **Usefulness of the framework.**

All participants consider this framework to be useful for the construction industry and regulatory organisations, since it allows for understanding of the implementation requirements.

5. **Comments and suggestions on areas that need improvement.**

The only suggestion made for improvement was like with the readiness tool to ensure its availability in other languages specially in Spanish.

10.5 Summary

This chapter discusses the development of an integrated framework for adopting Big Data in construction organisations. The framework was developed based on the findings of the previous chapters of this study and by combining different theories for technology innovation such as TOE, organisational change, and sustainability. The framework addresses research objective number seven (RO7): "To develop and validate a framework for the implementation of BD in the construction industry." The framework consists of four main stages: inputs, processes, outputs, and outcomes. The framework improves the organisations' understanding of the role of the drivers (input) behind BD adoption, the inter-relationships among the different factors and the actions to be taken (process) to adopt BD, the impacts of the technology on the organisation's sustainability performance (output), and the impact on the organisation's competitiveness in the longer term (outcome).

The developed framework is aimed at organisations in the construction industry that are looking to improve their processes through digital transformation and the adoption of BD, including those that have already started this process. The framework provides decision-makers with an understanding of the process of adopting BD and the steps undertaken to reach this goal.

Finally, the framework was validated by experienced professionals from different industries and countries. They concluded that the framework is a valuable tool since it will allow professionals to understand what should be considered as a strategy to implement BD.

CHAPTER 11. CONCLUSIONS AND RECOMMENDATIONS

11.1 Introduction

This chapter presents the conclusions and recommendations resulting from this study. The first section (Section 11.2) will revisit the research aim, objectives, and questions, followed by a review of the research process. Section 11.3 will review the key findings and their alignment with the research objectives. Section 11.4 will present the recommendations drawn from the study. Section 11.5 will review the research contributions. Finally, section 11.6 will explore the subsequent work that can be derived from this research.

11.2 Reflection of the Research Process

This section reviews the research aim and objectives, methodological process and key outputs, in order to provide a better understanding on how they have been addressed throughout this study's journey.

Table 11.1: Summary of the research process

Research Aim	This research aims to develop a framework for adopting Big Data concepts in the construction industry. This framework will provide guidelines for adopting concepts leading to sustainable development. To achieve this aim, the following objectives have been identified.
Research Objectives	1. To understand the benefits of BD for the DR Construction Industry. 2. To explore understanding the Big Data concept and its characteristics in the construction industry. 3. To investigate the drivers for implementing BD in the construction industry. 4. To explore the key strategies for BD adoption. 5. To explore the challenges when implementing BD in the construction industry. 6. To develop and evaluate a Big Data Readiness Assessment tool for construction organisations. 7. To develop and evaluate a framework for implementing BD in the construction industry.
Research Questions	1. What is BD and what are the benefits that it can provide to the construction industry? 2. What is the understanding of the construction industry of the Big Data concept, its relationship with the construction industry, and its characteristics?

	3. What are the drivers that drive the implementation of BD in the construction industry? 4. What are the key strategies for implementing BD in the construction industry? 5. What challenges do organisations and the construction industry face when adopting BD?
Research Classification	Exploratory study
Research Philosophy	Pragmatism
Research Approach	Inductive
Research Methodology	Qualitative
Research Strategy	Grounded theory
Data Collection	Systematic literature review and semi-structured interviews.
Sampling Methodology	Non-probabilistic
Number of Participants	21
Data Analysis	Thematic and content analysis
Research Outputs	• The levels of BD awareness in the Dominican Republic's construction industry. • The key drivers that have fuelled the need for implementing BD within the construction industry of the Dominican Republic. • The key strategies for implementing BD in the construction industry of the Dominican Republic. • The key challenges that the construction industry of the Dominican Republic is currently facing regarding the adoption of BD. • An organisation readiness assessment tool for adopting BD in construction organisations. • An integrated framework for BD adoption within the construction industry.

11.3 Key Findings and Conclusions

Research Objective 1: To understand the benefits of BD for the DR Construction Industry.

Research objective number one (RO1) was addressed in Chapter 2: Literature review, which in turn addressed research question number one (RQ1), specifically what is BD and what are the benefits that it can provide to the construction industry?

Generally, Big Data (BD) can be considered to be any significant amount of digital information. More specifically, it can be regarded as the cumulus of information that escapes the capacity of traditional tools for handling, process, transmitting, and overall managing said data (Miloslavskaya & Tolstoy, 2016). To be considered BD, the dataset has to possess specific characteristics such as volume, variety, velocity, and value (Tabesh et al., 2019). Big Data analysis involves extracting valuable insights from this big cumulus of information, allowing organisations to improve their decision-making process, delivering better services and customer experiences, entering new markets, and increasing revenue (Bange et al., 2015).

Big Data is a relatively young technology in digitally driven industries such as healthcare, retail, and telecommunications (Chen et al., 2020; Tabesh et al., 2019). Global BD adoption is growing exponentially with each passing day. By 2021, the BD market was expected to reach around $99 billion dollars (Kulkarni, 2019). However, successful adoption is tightly attached to digitally driven industries (Chen et al., 2020; Rabhi et al., 2019; Tabesh et al., 2019).

Although the construction industry is being challenged by technological devolvement that seeks to improve the way that construction projects are delivered, the industry is still struggling to adopt new technologies widely as it is being held back by slow innovation (Silverio Fernandez et al., 2019; Ngo et al., 2020; Srinavin et al., 2021; Hwang et al., 2022).

The industry's inability to embrace technological advancement contradicts the amount of digital data and the dependency that is growing in the construction sector at great speed, driven by the adoption of digital trends, software, and tools as well as the migration from paper-based project development (Chen et al., 2020; Caesarius & Hohenthal, 2018; Opoku et al., 2021). Despite the great reception that BD has had in other sectors and how every day more digital developments are pushing the construction industry to evolve at a much greater pace than ever, construction is still among the least digitalised industries today (Opoku et al., 2021; Abioye et al., 2021).

The overall benefits of BD implementation in construction offer a possible solution to the challenges faced by the industry both globally and in the Dominican Republic described in sections 1.2, 2.4 and 2.6. Many sources have highlighted how the benefits of BD can lead the industry towards sustainable development, impacting all areas of

sustainability and enabling the industry to deal with the demands of today's society. Many positive impacts can be achieved because of adopting BD in the construction industry. It will depend on the level of implementation and could include factors such as:

- Cost optimisation
- Increasing productivity and efficiency
- Potential risk identification
- Accurate budgeting
- Improved pricing
- Focus on local preferences
- Improved recruitment and working conditions
- B2B opportunities
- Innovation
- Better decision-making opportunities
- Resource optimisation
- Improved environmental risk assessments
- Understanding operations
- Better regulation
- Customer service and experience improvement

Moreover, there is an increase in the cases of BD adoption by construction companies worldwide which translates into specific instances in which the effects of technology can become tangible (Hwang et al., 2022). Such is the case of BD's application in the project lifecycle, where it provides improved decision-making and benefits all stakeholders (Stannard, 2021). The industry-wide adoption of BD in construction would mean a potential solution to unnecessary waste creation, the inefficient use of equipment and materials, and the inefficient project analysis of risks and costs. At the same time, the adoption would produce improved management efficiency, improved budget estimations, lower project risks, increased building efficiency, reduced environmental impacts, improved working conditions, and enhanced sustainability.

In the end, with the implementation of BD technology as part of the decision-making processes in the construction industry, the benefits include increased efficiency, reduced waste, the efficient satisfaction of user needs, improved project delivery, and an advancement towards the sustainable development of the industry.

Objective 2: To explore the understanding of the Big Data Concept and its characteristics in the construction industry.

Research objective number two (RO2) was addressed in Chapter number 5: Big Data awareness in the construction industry of the Dominican Republic, which in turn tackled research question number two (RQ2), what is the understanding of the construction industry of the Big Data concept, its relationship with the construction industry, and its characteristics?

To assess the level of awareness regarding the concept and characteristics of BD technology in the construction industry of the DR, the data collected was analysed by applying content analysis. Additionally, this research involved the situational awareness model developed by Endsley in 1995. Since its development, this model has been considered the most generally accepted interpretation of situational awareness (Stanton et al., 2001).

The results reveal the awareness of the industry when it comes to Big Data, showing that overall, there is a basic level of awareness prevailing within this field. Basic knowledge means that an in-depth and focussed homogenisation of the concept and its characteristics is required to ensure an industry-wide implementation of the technology.

Moreover, the results demonstrate that the concept of Big Data is generally known in the Dominican Republic's industry. This agrees with much of the literature indicating that in recent years, there has been an exponential increase in the use of both the term and the technology (Wang et al., 2020). Still, at the same time, there is a lack of understanding about the possible connection between BD and construction, thus recognising this as a challenge for implementation. Since most of the participants who knew about the technology were unaware of its applications in the industry, this was also supported by the high level of ignorance around BD requirements or characteristics, as reflected in the results. This denotes that the concept, conditions, and more technical aspects of the technology should reach a higher level of awareness before the technology can be fully adopted.

The lack of in-depth and homogenous understanding appears to be an issue that came to light in each area explored by this research in which it could be considered the main

problem, followed by the need for education and training aimed at present and future professionals to equip them with the tools that will allow them to identify, take advantage of, and implement technologies that will positively impact the industry in the future.

Additionally, the essential elements for data accumulation and transmission in the form of Cloud storage and data-generating and transmitting devices are already widely used in the Dominican Republic's industry, even when they haven't been recognised as such or put in place for BD purposes (Burguer, 2019; Wood, 2018).

In conclusion, there is a basic level of awareness about BD, its characteristics and how this technology could positively impact the construction industry. Therefore, it is necessary to create the means for increasing this awareness and understanding. Organisations could improve their processes by adopting BD in areas such as cost, waste management, and energy efficiency, to mention a few. Hence the need for exposing present and future professionals to the technological developments of the industry. However, the low level of awareness demonstrated by many of the participants could also represent a limitation for this study and affect its validity, since many of the insights provided were based on their experience with similar technologies and no BD.

Objective 3: To investigate the drivers for implementing BD in the construction Industry.

Research objective number three (RO3) was addressed in Chapter 6: Drivers for BD adoption in the construction industry of the Dominican Republic which in turn answered research question number three (RQ3), what are the drivers that drive the impulse of the implementation of BD in the construction industry?

Nine key drivers were identified as a result of this study. The data collected was subsequently examined using thematic analysis to determine the driving forces. The drivers identified by the participants were classified into internal and external according to their origin or influence on the organisation. The internal key drivers were the knowledge of BD benefits, the impact on competitiveness, technology awareness, the solution to the company needs, the company's cultural orientation towards technology, client requirements, and profit expectations. The external key drivers or factors that can influence the adoption of BD from outside the organisation were industry

motivation, regulatory framework, and technology change adaptability. These nine elements represent the influencing forces regarding BD adoption in the construction industry of the Dominican Republic.

The results show that factors such as knowledge of the benefits would not only improve the adoption of the technology but also be able to help overcome the resistance to change within construction organisations by providing attractive perks that decision-makers cannot resist such as a competitive advantage over their competitors and recognition as innovators.

Objective 4: To explore the key strategies for BD adoption.

Research objective number four (RO4) was addressed in Chapter 7: Strategies for BD implementation in the construction industry of the Dominican Republic, which in turn addressed research question number four (RQ4), what are the key strategies for implementing BD in the construction industry?

According to Dominican industry experts, this study identified four main strategies for Big Data adoption. These strategies, namely the promotion, standardisation and popularisation of BD concept and its benefits, investment in training and development of staff skills, support for the development of current technologies, as well as the inclusion of technology in the education curriculum of present and future professionals, will help construction companies with an interest in adopting Big Data as part of their organisations in the future develop an action plan and identify the steps they need to follow to achieve the successful adoption of the technology.

These strategies reflect the current low implementation state of BD technology in the construction industry of the Dominican Republic. Focus on the essential elements such as improving awareness, promoting investment in tools that benefit both the current projects of companies and the future adoption of technology, developing the capacities of workers to adopt this and other technologies, as well as the inclusion of the concept in education for current and future professional training.

Objective 5: To explore the challenges of implementing BD in the construction industry.

Research objective number five (RO5) was addressed in Chapter 8: Challenges faced by the adoption of BD in the construction industry of the Dominican Republic, which in

turn tackled research question number five (RQ5), specifically what challenges do organisations and the construction industry face when adopting BD?

The adoption of Big Data (BD) in the construction industry can provide a possible solution to the demands of the current needs of ongoing and future projects (Wong, 2020; Morrison, 2021). Still, integrating this technology has proven to be challenging, especially in less technologically driven industries such as construction. Understanding the key challenges to adopting BD in the construction industry is an essential part of implementing the technology. As a result of this research, seven main challenges were identified that hinder the adoption of BD in the construction industry of the Dominican Republic. The following challenges represent the situations that organisations must overcome to successfully adopt the technology.

- Lack of BD awareness
- High cost of investment
- Resistance to change
- Lack of government support and regulation
- Lack of technological expertise
- BD security concerns
- Lack of motivation from the stakeholders

The somewhat basic level of the identified challenges is a reflection of the current status of the industry and it relates to the overall basic level of awareness that the sector possesses about BD. Nevertheless, the challenges identified in this study will help companies better plan their technology adoption process by addressing all challenges and ensuring that both present and future professionals come to understand the technology and its benefits and become willing to adopt it.

Objective 6: To develop and evaluate the Big Data Readiness Assessment tool for construction organisations.

Research objective six (RO6) was addressed in Chapter 9: Organisation's readiness assessment tool for BD adoption.

A readiness assessment tool for BD adoption in construction has been developed and evaluated. The readiness tool is aimed at assisting construction organisations in assessing their readiness to adopt BD technology. Its development was based on the

study's findings and the literature review. Moreover, the readiness tool will allow organisations to identify their weaknesses, providing a roadmap for implementation.

The assessment tool is based on the TOE framework developed by Tornatzky, Fleischer, and Chakrabart in 1990. It covers the three main areas of technological innovation: technology, the organisation, and the environment. As such, the readiness tool assesses the organisation's readiness in these three areas which are evaluated individually through units of measure, providing a global score of preparedness for the organisation. Moreover, the tool will assist the organisation's decision-makers in understanding BD-related concepts, its requirements, and areas of improvement for a successful implementation.

Objective 7: To develop and evaluate a framework for implementing BD in the construction industry.

Research objective seven (RO7) was addressed in Chapter 10: Integrated framework for BD adoption in the construction industry.

An integrated framework for adopting Big Data in the construction industry has been developed and evaluated. The developed framework is intended for organisations within the construction industry that wish to adopt BD, thus promoting wider industrial adoption.

The framework was developed based on the findings of the previous chapters of this study and by combining different theories for technology innovation such as TOE, organisational change, and sustainability. The framework is based on a combination of the literature review and this study's previous findings. It consists of four main stages: inputs, processes, outputs, and outcomes. The framework improves the organisations' understanding of the role of the drivers (input) behind BD adoption, the inter-relationships among the different factors and the actions to be taken (process) to adopt BD, the impacts of the technology on the organisation's sustainability performance (output), and the impact on the organisation's competitiveness in the longer term (outcome).

The developed framework is aimed at organisations in the construction industry that are looking to improve their processes through digital transformation and the adoption of BD, including those that have already started this process. The framework provides

decision-makers with an understanding of the process of adopting BD and the steps needed to reach this goal.

11.4 Recommendations

11.4.1 Recommendations for the construction industry

- Dominican Republic's construction industry should include the stakeholders involved in the decision-making processes such as the organisation's employees, customer representatives, suppliers, and community members. Their input could play an essential role in ensuring successful BD adoption.
- There is an evident lack of in-depth and homogenous understanding of the BD concept and how it can be implemented in construction. Therefore, the industry should join in the efforts to promote the long and short-term impacts, thus supporting the adoption of the technology which will also help to overcome the intrinsic resistance to change in the industry.
- The fast changes in technology development, knowledge, and the constant environmental and social pressures must be met with continuous training and the development of new digital skills at all levels.
- Adopting new technologies such as BD is particularly challenging because of the high integration level required. Therefore, a broad array of stakeholders must be engaged inclusively and collaboratively with the commitment of the top management to achieving the successful implementation of BD in the organisations and, consequently, the industry.
- The technological, organisational, and environmental contexts surrounding the implementation of BD and other smart technologies should be considered prior to any adoption efforts. Regarding the technological and organisational contexts, organisations must ensure they have the necessary resources for implementation. The proposed readiness assessment tool may be of use for this purpose. Moreover, in terms of the environmental context, organisations must ensure that they have the support of stakeholders as well as keep abreast of the different regulatory frameworks. Lastly, organisational culture has been identified as a critical element when adopting BD. For a company to generate a change in its organisational culture, it needs to become more willing to take

risks, open to the participation of all members of the company, and creative and technologically driven.

- The Dominican Republic's construction industry should join in the effort alongside the government and international institutions to improve awareness, promote investment in BD tools, and develop digital skills.

11.4.2 Recommendations for construction organisations

- To satisfy the needs of today's society, construction organisations from the DR need to carefully consider the environmental, social, and economic issues of their business activities. Organisations should move away from traditional approaches and adopt more innovative and digitally driven methods to achieve sustainable goals.
- Organisations within the sector have a basic awareness of BD, its characteristics, and requirements. This low level showcases the significant knowledge gap that exists across the industry. Therefore, sharing the best practices, benefits and knowledge from high-level organisations is crucial for spreading the technology within the sector.
- For organisations to gain a competitive advantage due to the implementation of BD, the top management must increase the use of new technology and data management protocols across their processes and activities.
- To achieve the successful adoption of BD and, as a result, a successful change, the alignment with the organisation's vision and mission and the need for top management support are essential. Therefore, organisations must develop strategies to incorporate these new objectives at all levels.
- Considering the efficient use of the BD, organisations must ensure the development and training of their employees to acquire the skills and capabilities required to operate such IT systems.
- The scarcity of knowledge and expertise associated with BD represents an enormous challenge for construction organisations. Therefore, training programmes related to BD, navigating change, and incorporating new technologies will help the necessary leaders, managers, and change agents to better understand how to ensure long-term benefits from BD adoption.

- Construction organisations must commit to investing in the research and development of new solutions and opportunities to respond to the challenges currently faced.
- Construction organisations should make use of tools that allow them to identify their weaknesses when implementing change.

11.4.3 Recommendations for the Dominican Republic's government

- The Dominican Republic's government should push to enact regulations aimed at gradually implementing BD and digital technologies within construction projects to promote efficiency and transparency.
- The Dominican Republic's government should include the construction organisations who are developing a clear legal framework to regulate the construction activities in the country to increase the level of quality and ensure sustainable development.
- The Dominican Republic's government should commit to supporting the construction industry and its organisations by facilitating access points to new technologies and developing digital skills.
- The Dominican government should develop and implement a clear Technology Innovation framework that is easily applied through industry to the sector to ensure the organisations' complete understanding and the successful implementation of BD and other smart technologies.
- The Dominican government should regard the development of its educational system as of significant importance to help develop and nurture current and future professionals in the knowledge and skills that will be leading the industry in the future.
- The Dominican Republic's government should develop financial programmes to support the adoption of new technologies like BD and encourage organisations within the construction industry to explore and adopt these new technologies within its processes.

11.4.4 Recommendations for universities

- One of the results that can be highlighted from this study is the need for exposing both present and future professionals to technological developments with the potential to disrupt the industry. This will ease any implementation

efforts by drastically reducing one of the main challenges for change in the industry, which is resistance.

- Universities should promote the exploration of new technologies by encouraging their students to look into possible solutions to current issues.
- Universities should include, in the curriculum of future professionals, the development of essential digital skills, which will help them to adapt to the new technological developments of the industry.
- Universities must keep up to date with technological developments in order to provide their students with cutting edge skills.
- Universities should expose their students to the current issues faced by the industry and promote the search for possible solutions.

11.5 Contributions to Knowledge

The present study attempts to address multiple gaps and in doing so makes important contributions.

- First, the study extends the limited research on the understanding of Big Data concept, characteristics and its relationship with the construction industry, providing a homogeneous concept of Big Data, a reaffirmation of the main characteristics, and an account of the benefits that adopting this technology would produce for the construction industry.
- Second, the research provided insights into BD concept and characteristics outside the typical setting of developed countries.
- Third, the study identified critical drivers for BD adoption.
- Fourth, the study expanded the applications of the situational awareness model by assessing the level of knowledge of new technology in the construction industry.
- Fifth, the research provided a starting point for adopting BD and other smart technologies within the sector by exploring the strategies for BD adoption.

- Sixth, the study improved the chances of the construction industry of the Dominican Republic by exploring the challenges that inhibit the adoption of BD within construction organisations.
- Seventh, the findings support the existing research concerning the positive link between adopting BD and the industry's sustainable development.

The following contributions have been documented regarding management and policy:

- First, the research improves the understanding of managers on the multiple drivers that impact an organisation's ability to successfully adopt BD.
- Second, the study provides clarification on the complex relationship between the different drivers that influence the effective implementation of smart technologies like BD. The acknowledgement of these drivers will assist construction managers prepare for future BD adoption.
- Third, the research expands the knowledge on BD-related challenges, this will help stakeholders to make more accurate decisions when planning and adopting more appropriate strategies that ensure the success of the adoption efforts.
- Fourth, the study contributes to the understanding of the relationship between the adoption of BD and sustainable competitiveness. This correlation is essential for stakeholders as the knowledge can increase their awareness of sustainability and show them that investing in the technology will improve not only their organisations' social and environmental performance but also their economic performance.
- Fifth, the study expanded the organisation's capability to assess their readiness for adopting BD. The developed readiness assessment tool helps organisations evaluate their current ability to adopt BD while identifying any shortcomings. Moreover, organisations will be able to identify weaknesses in their infrastructure that may represent a challenge to BD adoption.
- Sixth, the research increased the industry capability of adopting BD. The developed framework will help policymakers understand the drivers, strategies and challenges that need to be considered to support the adoption of the

technology in the construction industry whose impact would translate into efficiency, transparency, and sustainable competitiveness for the sector.

In general, this study will benefit the construction industry of the Dominican Republic and its stakeholders, including organisations, decision-makers, employees, and policymakers, by providing a readiness assessment tool and a framework for the successful adoption of BD. This will result in the following:

- Improving the understanding and awareness of the concept of Big Data (BD) and its characteristics.
- Improving the awareness of the digitalisation of the processes in construction companies.
- Improving the awareness of the drivers that push for the adoption of BD within the construction industry from the perspective of the Dominican Republic. This improvement will allow decision-makers to better understand the drivers and ensure efficient and successful BD adoption.
- Assisting the top management and decision-makers to practically frame and build a roadmap towards adopting BD technology.
- Improving the awareness among organisations of the key strategies for adopting BD in construction organisations.
- Improving the awareness of the fundamental challenges inhibiting the implementation of BD in construction organisations.
- Assisting organisations within the construction industry to evaluate their current ability to adopt BD through the readiness tool and developing a roadmap for implementation.
- Guiding the top management and decision-makers through the developed framework to help them better understand the concept of BD as well as to help them implement, manage, and control the technology and measure their success.

11.6 Future Work

Despite the novel insights presented in this study, some areas for further research and development can be explored.

- This is an exploratory study. Its nature limits the value of some of its findings for generalisation purposes. Further research could benefit from a more elaborate design and better articulation. Furthermore, research into successful BD adoptions as a case study could help evaluate the level of impact generated by each of the outputs and how feasible the achievement is of the proposed long-term outcomes.
- The in-depth exploration of the cost-benefit factor stayed outside the scope of this study. Based on this, it is recommended to develop a case study of successful implementation containing a cost-benefit analysis of the technology implementation.
- During the evaluation process of the readiness assessment tool presented in Chapter 9, the interviewees offered suggestions that still need to be addressed. The inclusion of recommendations that can serve as a guide on how organisations can move forward if willing to implement BD after knowing their current status or developing readiness tools that would target specific processes within a construction organisation are some of the areas that can be further developed in the future.
- This investigation has addressed the strategies, motivations, and barriers to adopting BD in construction organisations. However, the impacts of specific processes within the industry should be further investigated.
- Prior to this research, there was no background as to the drivers, strategies, and challenges for adopting BD in the construction industry of developing countries. This investigation highlights what those aspects are. Future research should focus on showing the difference between the cultural aspects of distinct environments.

REFERENCES

Abdulkadri, A. and Evans, A. (2016) *An assessment of big data for official statistics in the Caribbean Challenges and opportunities Cardiovascular Risk Factor Calculation View project Technical Report View project*.

Abdullah, d. and Wern, G.C.M., 2011. An analysis of accidents statistics in Malaysian construction sector, *International Conference on E-business, Management and Economics* 2011, IACSIT Press Honk Kong, pp. 1-4.

Abioye, S.O., Oyedele, L.O., Akanbi, L., Ajayi, A., Davila Delgado, J.M., Bilal, M., Akinade, O.O. and Ahmed, A. (2021) Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges. *Journal of Building Engineering* [online]**, 44**pp. 103299

Aboubakar, M., Kellil, M. and Roux, P. (2022) A review of IoT network management: Current status and perspectives. *Journal of King Saud University - Computer and Information Sciences* [online]**, 34**(7), pp. 4163-4176

Abusalah, M. (2021) Innovation Management in Construction — Practical Approach. *Agile Insider*.

Aggarwal, R. and Ranganathan, P. (2019) Study designs: Part 2 - Descriptive studies. *Perspect Clin Res***, 1**pp. 34-36

Ahmed, R., Shaheen, S. and Philbin, S.P. (2022) The role of big data analytics and decision-making in achieving project success. *Journal of Engineering and Technology Management* [online]**, 65**pp.

Alaka, H.A., Oyedele, L.O., Owolabi, H.A., Bilal, M., Ajayi, S.O. and Akinade, O.O., 2018. A framework for big data analytics approach to failure prediction of construction firms. *Applied Computing and Informatics,* **16**(1-2), pp. 207-222.

Alaloul, W.S., Musarat, M.A., Rabbani, M.B.A., Iqbal, Q., Maqsoom, A. and Farooq, W. (2021) Construction Sector Contribution to Economic Stability: Malaysian GDP Distribution. *Sustainability (Basel, Switzerland)***, 13**(9), pp. 5012

Alam, S. (2016) *7 steps to build a big data culture in your company.* April 20, Huffington Post.

Alipour, M., Harris, D.K., Barnes, L.E., Ozbulut, O.E. and Carroll, J., 2017. Load-capacity rating of bridge populations through machine learning: Application of decision trees and random forests. *Journal of Bridge Engineering,* **22**(10), pp. 04017076.

Ara, J., Ali, S. and Shah, I., 2020. Monitoring schedule time using exponentially modified Gaussian distribution. *Quality Technology & Quantitative Management,* **17**(4), pp. 448-469.

Asadianfam, S., ShamsI, M. and Rasouli kenari, A., 2022. Hadoop Deep Neural Network for offending drivers. *Journal of Ambient Intelligence and Humanized Computing,* **13**(1), pp. 659-671.

Astalin, P.K. (2013) Qualitative research designs: A conceptual framework. *International journal of social science & interdisciplinary research***, 2**(1), pp. 118-124.

Aversa, J., Hernandez, T. and Doherty, S. (2021) Incorporating big data within retail organizations: A case study approach. *Journal of Retailing and Consumer Services***, 60**pp.

Awa, H.O., Ukoha, O., Emecheta, B. and Liu, S. (Reviewing Editor) (2016) Using T-O-E theoretical framework to study the adoption of ERP solution. Cogen Business & Management, 3(1). DOI: 10.1080/23311975.2016.1196571

Baduge, S.K., Thilakarathna, S., Perera, J.S., Arashpour, M., Sharafi, P., Teodosio, B., Shringi, A. and Mendis, P. (2022) Artificial intelligence and smart vision for building and construction 4.0: Machine and deep learning methods and applications. *Automation in Construction***, 141**pp. 104440

Bag, S., Pretorius, J.H.C., Gupta, S. and Dwivedi, Y.K. (2021) Role of institutional pressures and resources in the adoption of big data analytics powered artificial intelligence, sustainable manufacturing practices and circular economy capabilities. *Technological Forecasting and Social Change***, 163**pp. 120420

Baig, M.I., Shuib, L. and Yadegaridehkordi, E. (2019) Big data adoption: State of the art and research challenges. *Information Processing & Management***, 56**(6), pp. 102095

Baker, H.R., Smith, S.D., Masterton, G. and Hewlett, B., 2018. Failures in construction: Learning from everyday forensic engineering. *Forensic Engineering 2018: Forging Forensic Frontiers.* American Society of Civil Engineers Reston, VA, pp. 648-658.

Baker, J. (2011) The Technology–Organization–Environment Framework. *in Information Systems Theory.* New York, NY: Springer New York.

Balti, H., Ben Abbes, A., Mellouli, N., Farah, I.R., Sang, Y. and Lamolle, M. (2020) A review of drought monitoring with big data: Issues, methods, challenges and research directions. *Ecological Informatics***, 60**pp. 101136

Bange, C., Grosser, T. and Janoschek, N. (2015) *How Companies Benefit from Big Data,* Wurzburg, Germany: BARC.

Barr, A.L., Knight, L., França-Junior, I., Allen, E., Naker, D. and Devries, K.M. Methods to increase reporting of childhood sexual abuse in surveys: the sensitivity and specificity of face-to-face interviews versus a sealed envelope method in Ugandan primary school children. *BMC International Health and Human Right***, 17**(4), pp. 1-11.

Bass, S. (2007) IIED Briefing Paper: A New Era in Sustainable Development. *Management of Environmental Quality***, 18**(5).

Bechhofer, F. and Paterson, L. (2000) *Principles of Research Design in the Social Sciences.* 1st Edition ed. Routledge.

Bell, D., Lycett, M., Marshan, A. and Monaghan, A. (2021) Exploring future challenges for big data in the humanitarian domain. *Journal of Business Research***, 131**pp. 453-468

Bello, S.A., Oyedele, L.O., Akinade, O.O., Bilal, M., Davila Delgado, J.M., Akanbi, L.A., Ajayi, A.O. and Owolabi, H.A. (2021) Cloud computing in construction industry: Use cases, benefits and challenges. *Automation in Construction***, 122**pp. 103441

Bhandari, P. (2022) *Inductive Reasoning | Types, Examples, Explanation.* May 04

Bhandari, P. (2022) *What Is Deductive Reasoning? | Explanation & Examples.* May 04

Bhat, A. (2020) *The future of IT outsourcing: five emerging trends.* August 5.

Bilal, M., Oyedele, L.O., Qadir, J., Munir, K., Ajayi, S.O., Akinade, O.O., Owolabi, H.A., Alaka, H.A. and Pasha, M. (2016) *Big Data in the construction industry: A review of present status, opportunities, and future trends.*

Bilal, M., Oyedele, L.O., Akinade, O.O., Ajayi, S.O., Alaka, H.A., Owolabi, H.A., Qadir, J., Pasha, M. and Bello, S.A., 2016. Big data architecture for construction waste analytics (CWA): A conceptual framework. *Journal of Building Engineering,* **6**, pp. 144-156.

Bilal, M., Oyedele, L.O., Kusimo, H.O., Owolabi, H.A., Akanbi, L.A., Ajayi, A.O., Akinade, O.O. and Davila Delgado, J.M., 2019. Investigating profitability performance of construction projects using big data: A project analytics approach. *Journal of Building Engineering,* **26**.

Boadu, E.F., Wang, C.C. and Sunindijo, R.Y., 2020. Characteristics of the construction industry in developing countries and its implications for health and safety: an exploratory study in Ghana. *International journal of environmental research and public health,* **17**(11), pp. 4110.

Boland, M.R., Rusanov, A., So, Y., Lopez-Jimenez, C., Busacca, L., Steinman, R.C., Bakken, S., Bigger, J.T. and Weng, C. (2014) From expert-derived user needs to user-perceived ease of use and usefulness: A two-phase mixed-methods evaluation framework. *Journal of Biomedical Informatics***, 52**pp. 141-150

Bou Hatoum, M., Piskernik, M. and Nassereddine, H. (2020) *A Holistic Framework for the Implementation of Big Data throughout a Construction Project Lifecycle* International Association for Automation and Robotics in Construction (IAARC).

Boyd, D. and Crawford, K. (2012) Critical questions for big data: Provocations for a cultural, technological, and scholarly phenomenon. *Information, communication & society* [online]**, 15**(5), pp. 662-679.

Boynton, A.C. and Zmud, R.W. (1984) An Assessment of Critical Success Factors. *Sloan Management Review***, 4**(25), pp. 17-27

Brandín, R. and Abrishami, S. (2021) Information traceability platforms for asset data lifecycle: blockchain-based technologies. *Smart and Sustainable Built Environment* [online]**, (ahead-of-print)**.

Bratton, J. (2020) *Organizational leadership.* Sage.

Braun, V. and Clarke, V. (2006) Using thematic analysis in psychology. *Qualitative research in psychology***, 3**(2), pp. 77-101.

Britel, Z. and Cherkaoui, A. (2020) *Change Readiness Assessment for the Implementation of Building Information Modelling within a Construction Project Management Company* ACM.

Brown, R.B. (2006) *Doing Your Dissertation in Business and Management.* UK: SAGE Publications Ltd.

Bryman, A. (2016) *Social research methods.* Oxford university press.

Burger, R. (2019) *How the Construction Industry is Using Big Data.* February 03, last update [Accessed 01 October 2021].

Busch, P. and Jörgens, H. (2005) International patterns of environmental policy change and convergence. *European Environment***, 15**(2), pp. 80-101

Busetto, L., Wick, W. and Gumbinger, C. (2020) How to use and assess qualitative research methods. *Neurological Research and Practice***, 2**(1), pp. 14.

Caesarius, L.M. and Hohenthal, J. (2018) Searching for big data: How incumbents explore a possible adoption of big data technologies. *Scandinavian Journal of Management***, 34**(2), pp. 129-140.

Carrillo, P., Harding, J. and Choudhary, A. (2011) Knowledge discovery from post-project reviews. *Construction Management and Economics* [online]**, 29**(7), pp. 713-723.

Caulfield, J. (2019) *How to do thematic analysis*6 of September-last update [Accessed 28 May 2020].

Cavalcanti, D.R., Oliveira, T. and de Oliveira Santini, F. (2022) Drivers of digital transformation adoption: A weight and meta-analysis. *Heliyon***, 8**(2), pp. e08911.

Chalhoub, J., Ayer, S.K. and Ariaratnam, S.T. (2021) Augmented reality for enabling un- and under-trained individuals to complete specialty construction tasks. *Journal of Information Technology in Construction,* **26**pp. 128-143.

Chan, A.P.C., Chan, D.W.M., Chiang, Y.H., Tang, B.S., Chan, E.H.W. and Ho, K.S.K., 2004. Exploring critical success factors for partnering in construction projects. *Journal of Construction Engineering and Management,* **130**(2), pp. 188-198.

Chang, C. and Tsai, M., 2013. Knowledge-based navigation system for building health diagnosis. *Advanced Engineering Informatics,* **27**(2), pp. 246-260.

Chang, V., Xu, Y.K., Zhang, J. and Xu, Q. (2021) Research on intelligent manufacturing development approach for China's local valve industry. *Smart and Sustainable Built Environment*, **10**(2), pp. 293-321.

Charmaz, K. (2006) *Constructing grounded theory: A practical guide through qualitative analysis.* Sage.

Chatterjee, S., Chaudhuri, R., Vrontis, D. and Thrassou, A. (2022) Impacts of big data analytics adoption on firm sustainability performance. *Qualitative Research in Financial Markets***, (ahead-of-print)**.

Chehri, A., Zimmermann, A., Schmidt, R. and Masuda, Y. (2021) Theory and Practice of Implementing a Successful Enterprise IoT Strategy in the Industry 4.0 Era. *Procedia Computer Science***, 192**pp. 4609-4618.

Chen, P., Linc, C. and Wud, W. (2020) Big Data Management in healthcare: Adoption challenges and implications. *International Journal of Information Management***, 26**(1), pp. 1-2.

Chen, X. and Lu, W.S., 2018. Scenarios for applying Big Data in boosting construction: A review, *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate* 2018, Springer, pp. 1299-1306.

Cheng, G. and Tang, Y., 2013a. PortView: identifying port roles based on port fuzzy macroscopic behavior. *Journal of Internet Services and Applications,* **4**(1), pp. 9

Cheng, C., Leu, S., Cheng, Y., Wu, T. and Lin, C. (2012) Applying data mining techniques to explore factors contributing to occupational injuries in Taiwan's construction industry. *Accident Analysis & Prevention*, **48**pp. 214-222.

Choi, M., Ahn, S. and Seo, J. (2020) *VR-Based investigation of forklift operator situation awareness for preventing collision accidents.*

Chowdhury, M.F. (2015) Coding, sorting and sifting of qualitative data analysis: debates and discussion. *Quality & Quantity*, **49**(3), pp. 1135-1143.

Chuah, M.H. and Thurusamry, R. (2021) Challenges of big data adoption in Malaysia SMEs based on Lessig's modalities: A systematic review. *null*, **8**(1), pp. 1968191 Available at:<https://doi.org/10.1080/23311975.2021.1968191>.

Clemente, C. (2016) RD necesita promover construcción sostenible. *Listin Diario.* Accessed 25 January 2018]. Available at: <https://www.listindiario.com/economia/2016/03/01/409879/rd-necesita-promover-construccion-sostenible>.

Cohen, B. and Crabtree, D. (2006) *Semi-structured Interviews.*

Conelly, M. (2020) *The Kurt Lewin Change Management Model.* September 12, [Accessed 01 October 2021].

Creswell, J.W. (2013) *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* Thousand Oaks, CA.: Sage publications.

Creswell, J.W. (2014) *A concise introduction to mixed methods research.* [online] SAGE publications.

Creswell, J.W. and Creswell, J.D. (2017) Chapter 1: The Selection of a Research Approach. *in Research Design Qualitative, Quantitative, and Mixed Methods Approaches.* Michigan, USA: Sage Publishing, pp.3-22.

Creswell, J.W. and Creswell, J.D. (2018) *Research Design Qualitative, Quantitative, and Mixed Methods Approaches.* Fifth Edition ed. Los Angeles, USA: Sage Publishing.

Cross, S. (2018) *Smart Construction - a guide for housing clients,* Construction Leadership Council.

Crotty, M.J. (1998) The foundations of social research: Meaning and perspective in the research process. *The foundations of social research,* pp. 1-256.

Crouch, M. and McKenzie, H. (2006) The logic of small samples in interview-based qualitative research. *Social Science Information* [online]**, 45**(4), pp. 483-499 Available at:<https://doi.org/10.1177/0539018406069584>.

Das, M., Cheng, J.C. and Shiv Kumar, S., 2014. BIMCloud: a distributed cloud-based social BIM framework for project collaboration. *Computing in Civil and Building Engineering (2014).* pp. 41-48.

Davenport, T.H. and Bean, R. (2019) *Big Data and AI Executive Survey 2019: Data and Innovation How Big Data and AI are Accelerating Business Transformation,* January. Boston, USA: New Vantage Partners LLC.

Dawson, C. (2002) *Practical research methods: A user-friendly guide to mastering research.* How to books.

de Mattos, C.A. and Laurindo, F.J.B. (2017) Information technology adoption and assimilation: Focus on the suppliers portal. *Computers in Industry* [online]**, 85**pp. 48-57.

DeBara, D. (2019) *Make your business process more efficient in 5 simple steps.* May 21, [Accessed 26/06/2022].

DeJonckheere, M. and Vaughn, L.M. (2019) Semi structured interviewing in primary care research: a balance of relationship and rigour. *Family Medicine and Community Health* [online]**, 7**(2), pp. e000057

Demirdogen, G., Isik, Z. and Arayici, Y. (2019) Building Information Modelling (BIM) And Big Data Analytics for Construction Industry. *International Journal of Advances in Mechanical and Civil Engineering* (6).

Denzin, N.K. and Lincoln, Y.S. (2011) *The Sage handbook of qualitative research.* Sage.

Designing Buildings (2022) Relationship *management in construction,* July 29, -last update [Accessed 01/08/2022].

Dishman, D., Fallacaro, M.D., Damico, N. and Wright, M.C. (2020) *Adaptation and Validation of the Situation Awareness Global Assessment Technique for Nurse Anaesthesia Graduate Students*

Doloi, H., Sawhney, A. and Iyer, K.C., 2012. Structural equation model for investigating factors affecting delay in Indian construction projects. *Construction Management and Economics,* **30**(10), pp. 869-884.

Dlamini, S. (2012) Relationship of construction sector to economic growth. *School of Construction Management*.

Duggal, N. (2022) *Top 7 Benefits of Big Data and Analytics and Reasons to Consider It for Your Next Career Move.* July 14.

Dunphy, D.C. and Stace, D.A. (1988) Transformational and coercive strategies for planned organizational change: Beyond the OD model. *Organization Studies***, 9**(3), pp. 317-334.

Durga, A. and Singla, M.L. (2019) Impact of social media readiness on social media usage and competitive advantage. *in* Katuu, S. (ed). *Diverse Applications and Transferability of Maturity Models.* IGI Global.

ECLAC, Economic Commission for Latin America and the Caribbean (2022)*Preliminary overview of the economies of the Caribbean 2020–2021*. St. Louis: Federal Reserve Bank of St Louis.

Elghaish, F., Hosseini, M.R., Matarneh, S., Talebi, S., Wu, S., Martek, I., Poshdar, M. and Ghodrati, N. (2021) Blockchain and the 'Internet of Things' for the construction industry: research trends and opportunities. *Automation in Construction***, 132**pp. 103942.

Ellis, G. (2022) The Power of Augmented Reality (AR) in Construction. *Digital Builder.*

Endsley, M.R. (2014) Situation Awareness. *in* Zsambok,C. E. and Klein,G.(eds). *Naturalistic Decision Making.* New York, USA: Psychology Press, pp.269-284.

Experian (2020) *How big data is transforming the world – and your business.* June, last update 2022 [Accessed 11/07/2022].

Faizal, N., 2010. *Construction Industry and its characteristics.*

Fang, D., Chen, Y. and Wong, L., 2006. Safety climate in construction industry: A case study in Hong Kong. *Journal of Construction Engineering and Management,* **132**(6), pp. 573-584.

Fernandez,C. A. (2017) Desafíos de la construcción y el desarrollo sostenible en el país. *Listin Diario.* [Accessed 07 January 2018]. Available at: <https://www.listindiario.com/economia/2017/11/21/491501/desafios-de-la-construccion-y-el-desarrollo-sostenible-en-el-pais>.

Fernandez-Vidal, J., Antonio Perotti, F., Gonzalez, R. and Gasco, J. (2022) Managing digital transformation: The view from the top. *Journal of Business Research***, 152**pp. 29-41

Ferrance, E. (2000) *Action Research*, Providence, USA: Brown University.

Filipović, D., Lukić, A. and Lukić, M. (2020) Geospatial evaluation of Belgrade for the purposes of determination of suitable locations for the construction of PV plants. *Archives for Technical Sciences***, 1**(22), pp. 59-66.

Garyaev, N. and Garyaeva, V. (2019) Big data technology in construction. *E3S Web of Conferences***, 97**pp. 1032

Gbadamosi, A., Oyedele, L., Mahamadu, A., Kusimo, H., Bilal, M., Davila Delgado, J.M. and Muhammed-Yakubu, N. (2020) Big data for Design Options Repository: Towards a DFMA approach for offsite construction. *Automation in Construction***, 120**pp. 103388.

George, T. (2022) *Exploratory Research | Definition, Guide, & Examples.* May o6, [Accessed 01/08/2022].

George, T. and Merkus, J. (2022) *Explanatory Research | Definition, Guide & Examples.* May 07, [Accessed 01/08/2022].

Gerbl, M., McIvor, R., Loane, S. and Humphreys, P. (2015) A multi-theory approach to understanding the business process outsourcing decision. *Journal of World Business*, **50**(3), pp. 505-518.

Gersick, C.J. (1991) Revolutionary change theories: A multilevel exploration of the punctuated equilibrium paradigm. *Academy of management review* [online], **16**(1), pp. 10-36.

Glatthorn, A.A. and Joyner, R.L. (2005) *Writing the Winning Thesis or Dissertation: A Step-by-Step Guide.* Second ed. California, USA: Corwing Press.

Goddard,W. (2021) *Pros and Cons of Big Data.* May 4.

Gohil, H. and Ayer, A. *Insurance Fraud Detection and Prevention in The Era of Big Data Curbing Fraud by Application of Advanced Analytics Across Policy Lifecycle,* 2018: Wns.

Gong, J., Caldas, C.H. and Gordon, C., 2011. Learning and classifying actions of construction workers and equipment using Bag-of-Video-Feature-Words and Bayesian network models. *Advanced Engineering Informatics,* **25**(4), pp. 771-782.

Goodenough, A. and Waite, S. (2012) No title. *Real world research: a resource for users of social research methods in applied settings*.

Graetz, F., Rimmer, M., Lawrence, A. and Smith, A. (2006) *Managing organisational change.* 2nd Australasian ed. ed. Malden, Mass.: John Wiley & Sons. p. xii, 412.

Greeff, G. and Ghoshal, R. (2004) 15 - Change management. *in* Greeff,G. and Ghoshal,R.(eds). *Practical E-Manufacturing and Supply Chain Management.* Oxford: Newnes, pp.378-402.

Haggerty, R.A. (1989) *Dominican Republic: A Country Study,* Washington, United States of North America: U. S. Library of Congress.

Hagiu,A. (2021) *When Data Creates a Competitive Advantage (and When it Doesn't).* August 30, Harvard Business School. [Accessed 11/07/2022].

Han, Z. and Wang, Y., 2017. The Applied Exploration of Big Data Technology in Prefabricated Construction Project Management, *ICCREM 2017: Prefabricated Buildings, Industrialized Construction, and Public-Private Partnerships - Proceedings*

of the International Conference on Construction and Real Estate Management 2017 2017, pp. 71-78.

Hammersley, M. (2007) The issue of quality in qualitative research. *International Journal of Research & Method in Education*, **30**(3), pp. 287-305 DOI/10.1080/17437270701614782>.

Han, T., Ma, T., Fang, Z., Zhang, Y. and Han, C. (2022) A BIM-IoT and intelligent compaction integrated framework for advanced road compaction quality monitoring and management. *Computers and Electrical Engineering*, **100**pp. 107981

Han, Z. and Wang, Y., 2017. The Applied Exploration of Big Data Technology in Prefabricated Construction Project Management, *ICCREM 2017: Prefabricated Buildings, Industrialized Construction, and Public-Private Partnerships - Proceedings of the International Conference on Construction and Real Estate Management 2017* 2017, pp. 71-78.

Harikrishnan, A., Said Abdallah, A., Ayer, S.K., El Asmar, M. and Tang, P. (2021) Feasibility of augmented reality technology for communication in the construction industry. *Advanced Engineering Informatics*, **50**pp. 101363.

Harrison, H., Birks, M., Franklin, R. and Mills, J. (2017) Case study research: Foundations and methodological orientations *Forum qualitative Sozialforschung/Forum: qualitative social research*. pp.1-17.

Harwood, T.G. and Garry, T. (2003) An overview of content analysis. *The marketing review*, **3**(4), pp. 479-498.

Hellerstein, J. (2008) *Parallel Programming in the Age of Big Data.* November 09, [Accessed 11/07/2022].

Hernández-Aznar, E. (2017) La construcción sostenible se abre camino en el país. *Listin Diario.* [Accessed 25 January 2018]. Available at: <https://www.listindiario.com/economia/2017/06/30/472123/la-construccion-sostenible-se-abre-camino-en-el-pais>.

Hills, P. (2006) International Journal of Information Management. *International Journal of Information Management* [online], **26**(1), pp. 1-2 DOI/10.1016/j.ijinfomgt.2005.10.001>.

Hitchings, R. and Latham, A. (2020) Qualitative methods I: On current conventions in interview research. *Progress in Human Geography* [online]**, 44**(2), pp. 389-398 DOI/10.1177/0309132519856412>.

Hotjar. (2022) Qualitative data analysis guide. August 09.

House, R.J., Wright, N.S. and Aditya, R.N. (1997) Cross-cultural research on organizational leadership: A critical analysis and a proposed theory.

HRSA (2012) *Readiness Assessment & Developing Project Aims,* July 06.

Huang, Y. and Beck, J.L., 2013. Novel sparse Bayesian learning for structural health monitoring using incomplete modal data. *Computing in Civil Engineering (2013).* pp. 121-128.

Humble, N. and Mozelius, P. (2022) Content analysis or thematic analysis: Similarities, differences and applications in qualitative research *European Conference on Research Methodology for Business and Management Studies*. pp.76-81.

Hwang, Ngo and Teo (2022) *Challenges and Strategies for the Adoption of Smart Technologies in the Construction Industry: The Case of Singapore* American Society of Civil Engineers (ASCE).

Ismail, Bandi and Maaz (2018) An Appraisal into the Potential Application of Big Data in the Construction Industry. *International Journal of Built Environment and Sustainability***, 5**(2), pp. 145-154.

IT Chronicles (2022) *What is Big Data* [Accessed 01/08/2022].

ITA, The International Trade Administration (2017) *Dominican Republic Country Commercial Guide* October, [Accessed May 13, 2018].

ITU, I. T. U. (2012) Overview of the Internet of things ITU-T Study Group 20. ITU-T Y.4000/Y.206001/07/2021

Jahanger, Q.K., Louis, J., Pestana, C. And Trejo, D. (2021) Potential Positive Impacts of Digitalization of Construction-Phase Information Management for Project Owners. *Journal of Information Technology in Construction***, 26** (ISSN 1874-4753), pp. 1-22.

Januškaitė, V. and Užienė, L. (2015) *Intellectual Capital Measurements and National Strategy Development: Explaining the Gap.*

Jeong, S., Byun, J., Kim, D., Sohn, H., Bae, I.H. and Law, K.H., 2015. A data management infrastructure for bridge monitoring, *Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems 2015* 2015, SPIE, pp. 219-234.

Jiang, X. and Mahadevan, S., 2008. Bayesian probabilistic inference for nonparametric damage detection of structures. *Journal of Engineering Mechanics,* **134**(10), pp. 820-831.

Jiao, Y., Wang, Y., Zhang, S., Li, Y., Yang, B. and Yuan, L. (2013) A cloud approach to unified lifecycle data management in architecture, engineering, construction and facilities management: Integrating BIMs and SNS. *Advanced Engineering Informatics***, 27**(2), pp. 173-188

Jiao, Y., Zhang, S., Li, Y., Wang, Y., Yang, B. and Wang, L., 2014. An augmented MapReduce framework for Building Information Modelling applications, *Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design, CSCWD 2014* 2014, pp. 283-288.

Joffe, H. (2012) Thematic analysis. *in* Harper, D. and Thompson, A. R.(eds). *Qualitative research methods in mental health and psychotherapy: A guide for students and practitioners.* John Wiley & Sons.

Johansen, K.W., Nielsen, R., Schultz, C. and Teizer, J. (2021) Automated activity and progress analysis based on non-monotonic reasoning of construction operations. *Smart and Sustainable Built Environment* [online]**, (ahead-of-print)**, DOI/10.1108/SASBE-03-2021-0044.

Jones, K. (2018) *4 Major Challenges Facing the Construction Industry.* February 8, [Accessed 01/10/2021].

Joubert, A., Murawski, M. and Bick, M. (2021) Measuring the Big Data Readiness of Developing Countries – Index Development and its Application to Africa. *Information Systems Frontiers*, <doi.org/10.1007/s10796-021-10109-9.

Kalema, B.M. and Mokgadi, M. (2017) Developing countries organizations' readiness for Big Data analytics. *Problems and Perspectives in Management*, **15**(1), pp. 260-270.

Ketokivi, M. and Mantere, S. (2010) Two strategies for inductive reasoning in organizational research. *Academy of management review*, **35**(2), pp. 315-333.

Khan, R. A. (2008) Role of Construction Sector in Economic Growth: Empirical Evidence from Pakistan Economy. *First International Conference on Construction in Developing Countries (ICCIDC–I).* August 4-5, 2008. Karachi, Pakistan.

Khurshid, M.M., Zakaria, N.H., Rashid, A., Kazmi, R., Shafique, M.N. and Ahmad, M.N. (2019) Analyzing diffusion patterns of big open data as policy innovation in public sector. *Computers and Electrical Engineering* [online], **78**pp. 148-161 Available at:<http://dx.doi.org/10.1016/j.compeleceng.2019.07.010>.

Kim, H., Soibelman, L. and Grobler, F. (2008) Factor selection for delay analysis using knowledge discovery in databases. *Automation in Construction*, **17**(5), pp. 550-560.

Kim, J.-. and Kim, B.-., 2018. Analysis of Fire-Accident Factors Using Big-Data Analysis Method for Construction Areas. *KSCE Journal of Civil Engineering,* **22**(5), pp. 1535-1543.

King, A. (2015) *7 Benefits to Using Big Data for Small Businesses* [Accessed 05/12/2021].

King, A.P. and Aljabar, P. (2023) Chapter 14 - Machine learning. *in* King, A. P. and Aljabar, P.(eds). *Matlab® Programming for Biomedical Engineers and Scientists (Second Edition).* Academic Press.

Knowles, E.E.M. (2020) Strengths and Limitations of Harnessing Big Data to Understand the Genetics of Adoption and Mental Health. *Biological psychiatry; Brain Circuits and the Emergence of Schizophrenia*, **87**(8), pp. e21-e22

Kulkarni, R. (2019) Big Data Goes Big. *Forbes*.

Kumar, R. (2014) Research methodology: a step by step guide for beginners. *Nurse researcher*, **19**(4), pp. 45.

Lai, Y., Sun, H. and Ren, J. (2018) Understanding the determinants of big data analytics (BDA) adoption in logistics and supply chain management: An empirical investigation. *The International Journal of Logistics Management*.

Lakshmi, S. and Mohideen, M.A. (2013) Issues in reliability and validity of research. *International journal of management research and reviews*, **3**(4), pp. 2752.

Lam, H., Yang, J. and Au, S., 2018. Markov chain Monte Carlo-based Bayesian method for structural model updating and damage detection. *Structural Control and Health Monitoring,* **25**(4), pp. e2140.

Latham,J. (2020) *Qualitative Sample Size – How Many Participants is Enough?* Available at <https://www.drjohnlatham.com/many-participants-enough/>.

Leeds, R. (2020) *Top 4 challenges facing the construction industry.* Octubre 11, last update [Accessed 01/10/2021].

Leonard-Barton, D. and Kraws, W.A. (1985) Implementing New Technology. *Harvard Business Review*.

Leung, L., 2015. Validity, reliability, and generalizability in qualitative research. *Journal of family medicine and primary care,* **4**, pp. 324-7.

Levitt, H.M., Motulsky, S.L., Wertz, F.J., Morrow, S.L. and Ponterotto, J.G. (2017) Recommendations for designing and reviewing qualitative research in psychology: Promoting methodological integrity. *Qualitative psychology*, **4**(1), pp. 2.

Levy, A. (1986) Second-order planned change: Definition and conceptualization. *Organizational dynamics*, **15**(1), pp. 5-23

Lewis, L. (2019) *Organizational Change Creating Change Through Strategic Communication.* 2nd ed. ed. United Kingdom: Wiley.

Ley General de las Sociedades Comerciales y Empresas Individuales de Responsabilidad Limitada, No. 479-08.

Ley 1 - 12 Estrategia Nacional de Desarrollo 2030: MEPyD, Ministerio de Economía, Planificación y Desarrollo. (2012) Gobierno de la Republica Dominicana.

Li, M., Lu, F., Zhang, H. and Chen, J. (2020) Predicting future locations of moving objects with deep fuzzy-LSTM networks. *Transportmetrica A: Transport Science*, **16**(1), pp. 119-136.

Li, S., Dragicevic, S., Castro, F.A., Sester, M., Winter, S., Coltekin, A., Pettit, C., Jiang, B., Haworth, J., Stein, A. and Cheng, T. (2016) Geospatial big data handling theory and methods: A review and research challenges. *ISPRS Journal of Photogrammetry and Remote Sensing*, **115**pp. 119-133 Available at:<http://dx.doi.org/10.1016/j.isprsjprs.2015.10.012>.

Liao, C. and Perng, Y. (2008) Data mining for occupational injuries in the Taiwan construction industry. *Safety Science*, **46**(7), pp. 1091-1102.

Lin, J., Hu, Z., Zhang, J. and Yu, F., 2016. A natural-language-based approach to intelligent data retrieval and representation for cloud BIM. *Computer-Aided Civil and Infrastructure Engineering,* **31**(1), pp. 18-33.

Linder, L., Vionnet, D., Bacher, J.-. and Hennebert, J., 2017. Big Building Data-a Big Data Platform for Smart Buildings, *Energy Procedia* 2017, pp. 589-594.

Liu, R.-., Kuo, C.-., Yang, C.-., Chen, S.-. and Liu, J.-., 2017. On construction of an energy monitoring service using big data technology for smart campus, *Proceedings - 2016 7th International Conference on Cloud Computing and Big Data, CCBD 2016* 2017, pp. 81-86.

Lowenstein, M. (2017) *What Industries Have Been Least Disrupted by Tech?* July 28, Gerben Law Firm, PLLC.

Loyola, M., 2018. Big data in building design: A review. *Journal of Information Technology in Construction,* **23**, pp. 259-284.

Lozano, R. (2013) Are companies planning their organisational changes for corporate sustainability? An analysis of three case studies on resistance to change and their strategies to overcome it. *Corporate Social Responsibility and Environmental Management*, **20**(1), pp. 275-295.

Lu, W., Chen, X., Ho, D.C.W. and Wang, H., 2016. Analysis of the construction waste management performance in Hong Kong: The public and private sectors compared using big data. *Journal of Cleaner Production,* **112**, pp. 521-531.

Luo, A. (2019) *What is content analysis and how can you use it in your research?* [Accessed 28 May 2020].

Mahfouz, T.S., 2009. *Construction legal support for differing site conditions (DSC) through statistical modelling and machine learning (ML).* Iowa State University.

Manyika, J., Chui, M., Brown, B., Bughin, J., Dobbs, R., Roxburgh, C. and Hung Byers, A. (2011) *Big data: The next frontier for innovation, competition, and productivity.* McKinsey Global Institute.

Markard, J. and Truffer, B. (2008) Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy*, **37**(4), pp. 596-615.

Maroufkhani, P., Tseng, M., Iranmanesh, M., Ismail, W.K.W. and Khalid, H. (2020) Big data analytics adoption: Determinants and performances among small to medium-sized enterprises. *International Journal of Information Management*, **54**pp. 102190.

Marr, B. (2019) What's The Difference Between Structured, Semi-Structured and Unstructured Data? *Enterprise Tech*.

Martinez, G., Renukappa, S. and Suresh, S. (2021) Business model innovation in small enterprises from developing countries during COVID-19 outbreak: exploring drivers and BMI outcomes. *Int. J. Business Environment* [online](Y).

Mason, S. (2020) *Practice makes better? Testing a model for training program evaluators in situation awareness*

McCombes, S. (2022) *Descriptive Research Design | Definition, Methods & Examples.* May 5, [Accessed 01/08/2022].

McCombes, S. (2021) *Sampling Methods | Types and Techniques Explained*

Meadowcroft, J. (2007) National sustainable development strategies: features, challenges and reflexivity. *European Environment*, **17**(3), pp. 152-163 Available at:<http://onlinelibrary.wiley.com/doi/10.1002/eet.450/abstract>.

Meleen, M., September 28, 2021-last update, Difference Between Data and Information Explained. Available: https://examples.yourdictionary.com/difference-between-data-and-information-explained.html [March 04, 2023].

Mena, M. (2021) *El Big Bang del Big Data,* October 22.

MEPyD (2010) *Propuesta Estrategia Nacional de Desarrollo 2010 – 2030: Indicadores y metas,* Santo Domingo, Republica Dominicana: Ministerio de Economía, Planificación y Desarrollo.

Mercedes, C. (2015) Brecha entre la Percepción y la Realidad. *Acento Diario.* [Accessed 23 January 2018].

Middleton, F. (2022) *Reliability vs Validity in Research | Differences, Types & Examples.* August 26,

Miller, D. and Friesen, P.H. (1984) A longitudinal study of the corporate life cycle. *Management science* [online]**, 30**(10), pp. 1161-1183.

Miller, H.J. and Tolle, K., 2016. Big data for healthy cities: Using location-aware technologies, open data and 3D urban models to design healthier built environments. *Built Environment,* **42**(3), pp. 441-456.

Miloslavskaya, N. and Tolstoy, A. (2016) Big Data, Fast Data and Data Lake Concepts. *Procedia Computer Science* [online]**, 88**pp. 300-305

Mitrega, M., Forkmann, S., Zaefarian, G. and Henneberg, S.C. (2017) Networking capability in supplier relationships and its impact on product innovation and firm performance. *International journal of operations & production management***,** **37**(5), pp. 577-606

MITUR and Dominican Republic Tourism Ministry (2022) *About Dominican Republic* [Accessed 01/08/2022].

Mneney, J. and Van Belle, J. (2016) Big data capabilities and readiness of South African retail organisations *2016 6th International Conference-Cloud System and Big Data Engineering (Confluence)*. IEEE, pp.279-286.

Moavenzadeh, F. (1978) Construction industry in developing countries. *World Development***, 6**(1), pp. 97-116.

Moeni, S., Oudjehane, A., Baker, T. and Hawkins, W. (2017) Application of an interrelated UAS - BIM system for construction progress monitoring, inspection and project management. *PM World Journal*, **VI**(VIII).

Moharm, K. (2019) State of the art in big data applications in microgrid: A review. *Advanced Engineering Informatics*, **42**pp. 100945 Available at:<http://dx.doi.org/10.1016/j.aei.2019.100945>.

Mokhtariani, M., Sebt, M.H. and Davoudpour, H., 2017. Characteristics of the construction industry from the marketing viewpoint: challenges and solutions. *Civil engineering journal,* **3**(9), pp. 701-714.

Moore,D. T. (2014) Roadmaps and maturity models: Pathways toward adopting big data *Proceedings of the Conference for Information Systems Applied Research, Baltimore, MD*. pp.1508.

MOP, Ministerio de obras publicas, MINVU, Ministerio de Vivienda y Urbanismo, Minenergia, M.d.E. and MMA, Ministerio de Medio Ambiente (2013) *Estrategia Nacional de Construcción Sustentable,* December 06. Chile: Gobierno de Chile.

Morrison, R. (2021) *Big Data Becomes Pivotal to the Construction Industry.*

Moullin, J.C., Dickson, K.S., Stadnick, N.A., Albers, B., Nilsen, P., Broder-Fingert, S., Mukasa, B. and Aarons, G.A. (2020) *Ten recommendations for using implementation frameworks in research and practice* Springer Science and Business Media LLC.

Moullin, J.C., Sabater-Hernández, D., Fernandez-Llimos, F. and Benrimoj, S.I. (2015) *A systematic review of implementation frameworks of innovations in healthcare and resulting generic implementation framework* Springer Science and Business Media LLC.

Moura, I., Teles, A., Silva, F., Viana, D., Coutinho, L., Barros, F. and Endler, M. (2020) *Mental health ubiquitous monitoring supported by social situation awareness: A systematic review.*

Mourtzis, D., Vlachou, E. and Milas, N. (2016) Industrial Big Data as a Result of IoT Adoption in Manufacturing. *Procedia CIRP; 5th CIRP Global Web Conference - Research and Innovation for Future Production (CIRPe 2016)*, **55**pp. 290-295.

Mullins, L.J. (2007) *Management and organisational behaviour.* [online] Pearson education.

Munawar, H.S., Ullah, F., Qayyum, S. and Shahzad, D. (2022) Big Data in Construction: Current Applications and Future Opportunities. *Big data and cognitive computing* [online]**, 6**(1).

Munawar, H.S., Ullah, F., Heravi, A., Thaheem, M.J. and Maqsoom, A., 2021. Inspecting buildings using drones and computer vision: A machine learning approach to detect cracks and damages. *Drones,* **6**(1), pp. 5.

Muskan (2021) *IoT in Construction industry: Applications and Benefits.* May 05, last update [Accessed 11/07/2022].

Naoui, M.A., Lejdel, B., Ayad, M., Amamra, A. and kazar, O. (2021) Using a distributed deep learning algorithm for analyzing big data in smart cities. *Smart and Sustainable Built Environment***, 10**(1), pp. 90-105 Available at:<https://doi.org/10.1108/SASBE-04-2019-0040>.

Naoum-Sawaya, J. and Elhedhli, S. (2013) An interior-point Benders based branch-and-cut algorithm for mixed integer programs. *Annals of Operations Research***, 210**(1), pp. 33-55.

Narayan, S. and Tan, H.C., 2019. Adopting big data to forecast success of construction projects: A review. *Malaysian Construction Research Journal,* **6**(Special issue 1), pp. 132-143.

Nasrollahi, M. and Ramezani, J. (2020) A model to evaluate the organizational readiness for big data adoption. *International Journal of Computers, Communications and Control***, 15**(3).

NBS (2020) *10th National BIM Report,* May. London, UK: NBS Enterprises Ltd.

Neilson, A., Indratmo, Daniel, B. and Tjandra, S. (2019) Systematic Review of the Literature on Big Data in the Transportation Domain: Concepts and Applications. *Big Data Research***, 17**pp. 35-44 Available at:<http://dx.doi.org/10.1016/j.bdr.2019.03.001>.

Neuendorf, K.A. (2018) Content analysis and thematic analysis. *in Advanced research methods for applied psychology.* Routledge.

Newman, C., Edwards, D., Martek, I., Lai, J., Thwala, W. and Rillie, I. (2020) Industry 4.0 deployment in the construction industry: a bibliometric literature review and UK-based case study. *Smart and Sustainable Built Environment* [online]**, (ahead-of-print)**.

Ngo, J., Hwang, B. and Zhang, C. (2020) Factor-based big data and predictive analytics capability assessment tool for the construction industry. *Automation in Construction***, 110**pp. 103042

Nguyen, T. and Petersen, T.E. (2017) *Technology adoption in Norway: organizational assimilation of big data*, NORWEGIAN SCHOOL OF ECONOMICS.

Nik-Bakht, M., Lee, J. and Dehkordi, S.H. (2021) BIM-based reverberation time analysis. *Journal of information technology in construction***, 26**pp. 28-38.

Nikolopoulou, K., December 01, 2022-last update, What Is Purposive Sampling? | Definition & Examples [01/04/, 2023].

Northern Ireland business info (2022) *Change management*, Belfast, NI: Northern Ireland Government.

Ocean, J. (2021) *Top 12 Construction Issues & Challenges.* September 18, [Accessed 07/10/2021].

Odor, H.O. (2018) Organisational change and development. *European Journal of Business and Management***, 10**(7), pp. 58-66.

OECD/Eurostat (2019) Measuring external factors influencing innovation in firms. *in Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation.* 4th ed. Paris/ Eurostat, Luxembourg: OECD Publishing, pp.145-162.

Oladokun, M.G., Isang, I.W. and Emuze, F. (2021) Towards sustainability practices deployment in building construction projects in Nigeria. *Smart and Sustainable Built Environment***, 10**(4), pp. 759-780 Available at:<https://doi.org/10.1108/SASBE-04-2019-0053>.

Olszak, C. and Mach-Król, M. (2018) A conceptual framework for assessing an organization's readiness to adopt big data. *Sustainability*, **10**(10), pp. 3734

Opoku, D.J., Perera, S., Osei-Kyei, R. and Rashidi, M. (2021) Digital twin application in the construction industry: A literature review. *Journal of Building Engineerin*, **40**pp. 102726

Oracle (2020) *Top big data analytics use cases Oracle*. [Accessed 11/07/2022].

Park, J. and Cai, H. (2017) WBS-based dynamic multi-dimensional BIM database for total construction as-built documentation. *Automation in Construction*, **77**pp. 15-23.

Paycor (2019) *Overcoming Employee Resistance to Change in the Workplace.* July 17, last update [Accessed 01 October 2021].

Petrov, C. (2022) *25+ Impressive Big Data Statistics for 2022.* Jun 22, last update [Accessed 11/07/2022].

Phelps, R.P. (2011) Standards for educational & psychological testing. *New Orleans, LA: American Psychological Association*.

Pietrzyk, K., 2015. A systemic approach to moisture problems in buildings for mould safety modelling. *Building and Environment,* **86**, pp. 50-60.

Pigni, F., Piccoli, G. and Watson, R. (2016) Digital Data Streams: Creating Value from the Real-Time Flow of Big Data. *California management review* [online], **58**(3), pp. 5-25 Available at:<https://doi.org/10.1525/cmr.2016.58.3.5>.

Polit, D.F. and Beck, C.T. (2010) *Generalization in quantitative and qualitative research: Myths and strategies.*

Ponterotto, J.G. (2005) Qualitative research in counseling psychology: A primer on research paradigms and philosophy of science. *Journal of counseling psychology*, **52**(2), pp. 126.

Presidency of the Dominican Republic (2021) *Ministro de Obras Públicas asegura que la construcción fue el sector de mayor aporte al crecimiento económico del país en 2021*December 06, last update [Accessed 01/03/2022].

Purvis, R.L., Sambamurthy, V. and Zmud, R.W. (2001) The assimilation of knowledge platforms in organizations: An empirical investigation. *Organization science*, **12**(2), pp. 117-135.

Qadir, Z., Ullah, F., Munawar, H.S. and Al-turjman, F., 2021. Addressing disasters in smart cities through UAVs path planning and 5G communications: A systematic review. *Computer Communications,* **168**, pp. 114-135.

Quee, W. (1999) *Marketing research.* Oxford, UK: Butterworth-Heinemann.

Rabhi, L., Falih, N., Afraites, A. and Bouikhalene, B. (2019) Big Data Approach and its applications in Various Fields: Review. *Procedia Computer Science*, **155**pp. 599-605 Available at:<http://dx.doi.org/10.1016/j.procs.2019.08.084>.

Raguseo, E. (2018) Big data technologies: An empirical investigation on their adoption, benefits and risks for companies. *International Journal of Information Management* [online], **38**(1), pp. 187-195 Available at:<http://dx.doi.org/10.1016/j.ijinfomgt.2005.10.001>.

Ram, J., Afridi, N. and Khan, K.A. (2019) Adoption of Big Data analytics in construction: development of a conceptual model. *Built Environment Project and Asset Management*, **9**.

Ram, Afridi and Khan (2019) Adoption of Big Data analytics in construction: development of a conceptual model. *Built Environment Project and Asset Management* [online], **9**(4), pp. 564-579.

Rao, S. (2022) The Benefits of AI In Construction. *Constructible*.

Reason, P. and Bradbury, H. (2001) *Handbook of action research: Participative inquiry and practice.* Sage.

Reyes Veras, P. (2015) *An Investigation on the Implementation and Situation of Sustainable Construction Practices in the Dominican Republic.* University of Wolverhampton.

Reyes Veras, P., Renukappa, S. and Suresh, S. (2021) *Awareness of Big Data concept in the Dominican Republic construction industry: an empirical study.* Emerald.

Reyes Veras, P., Renukappa, S. and Suresh, S. (2022), *"Awareness of Big Data concept in the Dominican Republic construction industry: an empirical study*", Construction Innovation, Vol. 22 No. 3, pp. 465-486. https://doi.org/10.1108/CI-05-2021-0090

Reynoso Vanderhorst, H., Suresh, S. and Renukappa, S. (2019) *Systematic Literature Research of the Current Implementation of Unmanned Aerial System (UAS) in the Construction Industry*.

Republica Dominicana*Ley No. 1-12 Que Establece la Estrategia Nacional de Desarrollo: Abel Rodirguez del Orbe. Gaceta Oficial (Separata), 2012-01-26, núm. 10656, 60 págs.* (2012) Santo Domingo, Republica Dominicana: Congreso Nacional de la Republica Dominicnana.

Rodriguez, A.K.S. (2020) *Implementation of Building Information Modelling in the Dominican Republic Construction Industry.* University of Wolverhampton.

Rowley, J., 2007. The wisdom hierarchy: representations of the DIKW hierarchy. *Journal of Information Science,* **33**(2), pp. 163-180.

Rune Todnem, B. (2005) Organisational change management: A critical review. *Journal of change management***, 5**(4), pp. 369-380.

Russel, D. (2007) The United Kingdom's sustainable development strategies: leading the way or flattering to deceive? *European Environment: The Journal of European Environmental Policy (Wiley)***, 17**(3), pp. 189-200.

Sambasivan, M. and Soon, Y.W., 2007. Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management,* **25**(5), pp. 517-526.

Sagiroglu,S. and Sinanc,D. (2013) Big data: A review - *2013 International Conference on Collaboration Technologies and Systems (CTS).* pp.42-47.

Salleh, K.A. and Janczewski, L. (2019) Security Considerations in Big Data Solutions Adoption: Lessons from a Case Study on a Banking Institution. *Procedia Computer Science; CENTERIS 2019 - International Conference on ENTERprise Information Systems / ProjMAN 2019 - International Conference on Project MANagement / HCist*

2019 - International Conference on Health and Social Care Information Systems and Technologies, CENTERIS/ProjMAN/HCist 2019 [online]**, 164**pp. 168-176.

Sarkar, D. and Modi, R. (2015) Applications of building information modelling (BIM) to real estate projects of Ahmedabad. *International Advanced Research Journal in Science, Engineering and Technology***, 2**(9), pp. 54-58.

Sarrakh, R. (2021) *Evaluation of sustainable strategies adoption for competitiveness within the Qatar oil and gas sector.* University of Wolverhampton.

Saunders, M., Lewis, P. and Thornhill, A. (2009) *Research methods for business students.* Pearson education.

Saunders, M., Lewis, P. and Thornhill, A. (2007) Research methods. *Business Students 4th edition Pearson Education Limited, England*.

Sayah, Z., Kazar, O., Lejdel, B., Laouid, A. and Ghenabzia, A. (2021) An intelligent system for energy management in smart cities based on big data and ontology. *Smart and Sustainable Built Environment***, 10**(2), pp. 169-192 Available at:<https://doi.org/10.1108/SASBE-07-2019-0087>.

Schueffel, P. (2017) *The concise FINTECH COMPENDIUM.* Switzerland: School of Management Fribourg. p. 2.

Seagate (2020) *Rethink Data: Put More of Your Business Data to Work - From Edge to Cloud,* July. United: Seagate Technology LLC.

Sebastian-Coleman, L. (2013) Chapter 13 - Directives for Data Quality Strategy. *in* Sebastian-Coleman, L. (ed). *Measuring Data Quality for Ongoing Improvement.* Boston: Morgan Kaufmann.

Segaran, T. and Hammerbacher, J. (2009) *Beautiful Data: The Stories Behind Elegant Data Solutions.* [online] O'Reilly Media.

Sepasgozar, S.M., Karimi, R., Shirowzhan, S., Mojtahedi, M., Ebrahimzadeh, S. and McCarthy, D., 2019. Delay causes and emerging digital tools: A novel model of delay analysis, including integrated project delivery and PMBOK. *Buildings,* **9**(9), pp. 191.

Shah, C., 2023. The past, the present, and the future of information and data sciences: A pragmatic view. *Data and Information Management,* pp. 100028.

Shahzad, M., Qu, Y., Rehman, S.U. and Zafar, A.U. (2022) Adoption of green innovation technology to accelerate sustainable development among manufacturing industry. *Journal of Innovation & Knowledge*, **7**(4), pp.

Sharif, M., Mercelis, S., Van Den Bergh, W. and Hellinckx, P., 2017. Towards real-time smart road construction: Efficient process management through the implementation of internet of things, *ACM International Conference Proceeding Series* 2017, pp. 174-180.

Shepheard, M. (2019) *Future technology in government.* May 2022-last update.

Shirowzhan, S. and LIM, S., 2014. Autocorrelation statistics-based algorithms for automatic ground and non-ground classification of Lidar data, *ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction* 2014, IAARC Publications, pp. 1.

Shvindina, H. (2016) The applicability of the social development and organization development theories at the enterprise. *Economic Processes Management: International Scientific E-Journal*, **4.**

Siddiqui, S.Q., Ullah, F., Thaheem, M.J. and Gabriel, H.F., 2016. Six Sigma in construction: a review of critical success factors. *International Journal of Lean Six Sigma,* **7**(2), pp. 171-186.

Silva, J., Hernandez, L., Crissien, T., Pineda Lezama, O.B. and Romero, J. (2019) Big Data Aplication for Selecting Theses Topics. *Procedia Computer Science; The 10th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN-2019) / The 9th International Conference on Current and Future Trends of Information and Communication Technologies in Healthcare (ICTH-2019) / Affiliated Workshops*, **160**pp. 538-542.

Silverio Rodriguez, A.K. (2020) *Implementation of building information modelling in the Dominican Republic construction industry.* University of Wolverhampton.

Silverio-Fernandez, M., Renukappa, S. and Suresh, S. (2019) Evaluating critical success factors for implementing smart devices in the construction industry: An empirical study in the Dominican Republic. *Engineering, Construction and Architectural Management*, **26**(8), pp. 1625-1640.

Siu, M.F., Ekyalimpa, R., Lu, M. and Abourizk, S., 2013. Applying regression analysis to predict and classify construction cycle time. *Computing in Civil Engineering (2013).* pp. 669-676.

S. Kaisler, F. Armour, J. A. Espinosa and W. Money. (2013) Big Data: Issues and Challenges Moving Forward - *2013 46th Hawaii International Conference on System Sciences*. pp.995-1004.

Small, M. (2019) *Big Data Analytics - Security and Compliance Challenges in 2019,* April. Kuppingercole.

Snyder, H. (2019) Literature review as a research methodology: An overview and guidelines. *Journal of Business Research***, 104**pp. 333-339.

Srinavin, K., Kusonkhum, W., Chonpitakwong, B., Chaitongrat, T., Leungbootnak, N. and Charnwasununth, P. (2021) Readiness of Applying Big Data Technology for Construction Management in Thai Public Sector. *Journal of advances in information technology***, 12**(1), pp. 1-5.

S. Shah, C. B. Soriano and A. D. Coutroubis. (2017) Is big data for everyone? the challenges of big data adoption in SMEs - *2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*. pp.803-807.

Stannard,L. (2021) *Big Data is Taking the Construction Industry to New Heights — Here's How.* July 30, [Accessed 07/07/2021].

Stanton, N.A., Chambers, P.R. and Piggott, J., 2001. Situational awareness and safety. Safety Science, 39(3), pp. 189-204.

Steinfeld, C. (2003) *United Nations Division for Sustainable Development.* p. 1435-1436.

Steurer, R. and Hametner, M. (2013) Objectives and Indicators in Sustainable Development Strategies: Similarities and Variances across Europe. *Sustainable Development***, 21**(4), pp. 224-241 Available at:<http://dx.doi.org/10.1002/sd.501>.

Steurer, R. and Martinuzzi, A. (2007) From environmental plans to sustainable development strategies. *European Environment: The Journal of European Environmental Policy (Wiley)***, 17**(3), pp. 147-151

Stobierski,T. (2020) *Organizational Change Management: What It Is & Why It's Important .* January 21, Harvard Business School. [Accessed 11/07/2022].

Strang, K. (2015) *The Palgrave handbook of research design in business and management.* Springer.

Strauss, A. and Corbin, J.M. (1998) *Grounded theory in practice.* Sage.

Streefkerk,R. (2022) *Inductive vs Deductive Reasoning | Difference & Examples.* May 04.

Suddaby, R. (2006) From the editors: What grounded theory is not. *Academy of management journal***, 49**(4), pp. 633-642.

Sun, S., Cegielski, C.G., Jia, L. and Hall, D.J. (2018) Understanding the factors affecting the organizational adoption of big data. *Journal of computer information systems***, 58**(3), pp. 193-203.

Surbhi,S. (2017) *Difference Between Survey and Experiment.* September 28, [Accessed 07/07/2021].

Sydorenko,I. (2021) *Big Data and Its Business Impacts: Benefits, Challenges, and Use Cases.* January 4, [Accessed 11/07/2022].

Tabesh, P., Mousavidin, E. and Hasani, S. (2019) Implementing big data strategies: A managerial perspective. *Business Horizons* [online]**, 62**(3), pp. 347-358 Available at:<http://dx.doi.org/10.1016/j.bushor.2019.02.001>.

Tamiminia, H., Salehi, B., Mahdianpari, M., Quackenbush, L., Adeli, S. and Brisco, B. (2020) Google Earth Engine for geo-big data applications: A meta-analysis and systematic review. *ISPRS Journal of Photogrammetry and Remote Sensing* [online]**, 164**pp. 152-170 Available at:<http://dx.doi.org/10.1016/j.isprsjprs.2020.04.001>.

TATVASOFT (2021) *Top Big Data Adoption Challenges Faced by Cxos* August 3, last update [Accessed 01/10/2021].

Teddlie, C. and Tashakkori, A. (2011) Mixed methods research. *The Sage handbook of qualitative research***, 4**pp. 285-300.

Tekton (2017) ¿Qué está pasando con la construcción sostenible en República Dominicana?

Tils, R. (2007) The German sustainable development strategy: facing policy, management and political strategy assessments. *European Environment: The Journal of European Environmental Policy (Wiley)***, 17**(3), pp. 164-176.

Todnem, R. (2005) Organisational change management: A critical review. *null***, 5**(4), pp. 369-380 Available at:<https://doi.org/10.1080/14697010500359250>.

Tornatzky, L.G., Fleischer, M. and Chakrabarti, A.K. (1990) *The processes of technological innovation.* Lexington, Mass: Lexington Books. p. 298.

Tranfield, D., Denyer, D. and Smart, P. (2003) Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management* [online]**, 14**(3), pp. 207-222.

Trost, S.M. and Oberlender, G.D., 2003. Predicting accuracy of early cost estimates using factor analysis and multivariate regression. *Journal of Construction Engineering and Management,* **129**(2), pp. 198-204.

TWB, T.W.B. (2022) *The World Bank in Dominican Republic,* April 13.

Tyagi, S. (2017) *What Does Big Data Mean For Sustainability?* January 24, [Accessed 01/07/2021].

Ullah, F., Thaheem, M.J., Siddiqui, S.Q. and Khurshid, M.B., 2017. Influence of Six Sigma on project success in construction industry of Pakistan. *The TQM Journal,* **29**(2), pp. 276-309.

UN, United Nations (2022) *Member States of the United Nations.* [Accessed 14/04/2022].

UN (2015) *United Nations Millennium Development Goals and Beyond.* [Accessed 14 November 2017].

UN, United Nations (2022) *Big Data for Sustainable Development.* [Accessed 11/07/2022].

USGS, United States Geological Survey *What is a geographic information system (GIS)?* [Accessed 01/07/2022].

Valdez Albizu, H. (2021) *Resultados preliminares de la economía dominicana enero-marzo 2021,* Abril. Santo Domingo, D. N., Republica Dominicana: Banco Central de la Republica Dominicana.

Van de Ven, Andrew H and Poole, M.S. (1995) Explaining development and change in organizations. *Academy of management review* [online]**, 20**(3), pp. 510-540.

Vanderhorst, H.R., Suresh, S., Renukappa, S. and Heesom, D. (2021) Strategic framework of Unmanned Aerial Systems integration in the disaster management public organisations of the Dominican Republic. *International Journal of Disaster Risk Reduction***, 56**pp. 102088.

Vellante, B. (2021) 7 Ways Construction Contractors Can Leverage the Power of Big Data. *Construction Innovation*.

Walliman, N. (2010) *Research methods: The basics.* 1st Edition ed. London, UK: Routledge. p. 7.

Wang, D., Fan, J., Fu, H. and Zhang, B., 2018. Research on optimization of big data construction engineering quality management based on RnN-LSTM. *Complexity,* **2018**.

Wang, Y., Wang, S., Yang, B., Zhu, L. and Liu, F. (2020) Big data driven Hierarchical Digital Twin Predictive Remanufacturing paradigm: Architecture, control mechanism, application scenario and benefits. *Journal of Cleaner Production***, 248**pp. 119299 Available at:<http://dx.doi.org/10.1016/j.jclepro.2019.119299>.

Warner Burke, W. and Litwin, G.H. (1992) A Causal Model of Organizational Performance and Change. *Journal of Management* [online]**, 18**(3), pp. 523-545.

Wattanajantra, A. (2020) *How to make more money with big data and predictive analytics.* January 30, last update.

Wedawatta, G., Ingirige, M. and Amaratunga, R. (2011) *Case study as a research strategy: Investigating extreme weather resilience of construction SMEs in the UK.* University of Salford.

WEF, The Wolrd Economic Forum (2022) *Future-Readiness Benchmarking Tool.* The World Economic Forum.

Weiss, K. (2018) *Integrating GIS and BIM: Construction Technology of the Future.* August 24, last update [Accessed 11/07/2022].

Welch, T.F. and Widita, A. (2019) Big data in public transportation: a review of sources and methods. *Transport Reviews*, **39**(6), pp. 795-818.

Whelan-Berry, K.S., Gordon, J.R. and Hinings, C.R. (2003) The relative effect of change drivers in large-scale organizational change: An empirical study. *in Research in organizational change and development.* Emerald Group Publishing Limited.

Wild, C., Stricka, M. and Patera, N. (2017) *Guidance for the development of a National HTA-strategy.*

Willar, D., Waney, E.V.Y., Pangemanan, D.D.G. and Mait, R.E.G. (2021) Sustainable construction practices in the execution of infrastructure projects. *Smart and Sustainable Built Environment*, **10**(1), pp. 106-124 Available at:<https://doi.org/10.1108/SASBE-07-2019-0086>.

Wisker, G. (2017) *The postgraduate research handbook: Succeed with your MA, MPhil, EdD and PhD.* Bloomsbury Publishing.

Woiceshyn, J. and Daellenbach, U. (2018) Evaluating inductive vs deductive research in management studies: Implications for authors, editors, and reviewers. *Qualitative research in organizations and management: An International Journal*.

Wong, M. (2020) *How Big Data and Analytics are Transforming the Construction Industry.* January 6, last update ESUB Construction Software.

Wright, M.G. and Williams, T.P., 2001. Using bidding statistics to predict completed construction cost. *The Engineering Economist,* **46**(2), pp. 114-128.

Wu, C., Buyya, R. and Ramamohanarao, K. (2016) Chapter 1 - Big Data Analytics = Machine Learning + Cloud Computing. *in* Buyya, R., Calheiros, R. N. and Dastjerdi, A. V.(eds). *Big Data.* Morgan Kaufmann.

Wu, J., Li, H., Liu, L. and Zheng, H. (2017) Adoption of big data and analytics in mobile healthcare market: An economic perspective. *Electronic Commerce Research and Applications*, **22**pp. 24-41

Wysokińska, Z. (2017) Millenium Development Goals/UN and Sustainable Development Goals/UN as Instruments for Realising Sustainable Development Concept in the Global Economy. *Comparative Economic Research***, 20**(1), pp. 101-118

Ye, F.Y. and Ma, F., 2023. An essay on the differences and linkages between data science and information science. *Data and Information Management,* pp. 100032.

Yousif, O., Zakaria, R., Aminudin, E., Yahya, K., Sam, A., Singaram, L., Munikanan, V., Yahya, M., Wahi, N. and Shamsuddin, S. (2021) Review of Big Data Integration in Construction Industry Digitalization. *Frontiers in Built Environment***, 7**.

Yu, T., Liang, X. and Wang, Y., 2020. Factors Affecting the Utilization of Big Data in Construction Projects. *Journal of Construction Engineering and Management,* **146**(5).

Zhang, J., Ouyang, Y., Ballesteros-Pérez, P., Li, H., Philbin, S.P., Li, Z. and Skitmore, M. (2021) Understanding the impact of environmental regulations on green technology innovation efficiency in the construction industry. *Sustainable Cities and Society***, 65**pp. 102647

Zhang, Y., Luo, H. and He, Y., 2015. A System for Tender Price Evaluation of Construction Project Based on Big Data, *Procedia Engineering* 2015, pp. 606-614.

Zina, O. (2021) *The essential guide to doing your research project.* [online] Sage. p. 85.

APPENDIX A: DATA EXTRACTION FORM

Reviewer:		Date:	
Author:		Year:	
Journal:			
Research Methodology:			
Participants:			
Emerging themes:			
Synthesis:			
Record:			

APPENDIX B: INVITATION EMAIL SENT TO PARTICIPANTS

Information Sheet

Adoption of Big Data Concepts in the Construction Industry towards Sustainability

Dear Potential Participant,

My name is Paola Reyes and I am a research student at the University of Wolverhampton. As a part of my program I am carrying out a study into the adoption of Big Data Concepts in the Construction Industry with the aim of adopting more sustainable ways of practice. I would like to invite you to participate in the above research project, as you are possibly influential for the decision-making process and data managing within your company.

If you agree to participate you will be asked to:

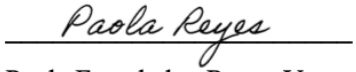
· Participate in an interview (of maximum 30 minute's duration) with me to answer questions regarding Big Data and Data Management. Questions will be topic specific and not of a personal nature, and you will not be asked to reveal any information which your organization would regard as sensitive and not for public disclosure. You can choose not to answer questions.

· Complete the attached consent form and return it to me.

With your agreement, interviews will be recorded then transcribed onto a computer system. You may review, edit or erase the transcripts and recordings of your interview if you wish to do so. Recordings will then be destroyed. Your responses will be treated as confidential and computer transcripts will not contain references to any persons (including yourself) or organizations. Such references will be replaced by codes known only to me, and all data will be stored securely.

Once completed a summary of results will be available at the conclusion of this research study. If you wish to obtain a copy of these results, please provide your contact details. Please note that all data gathered for this research will be stored securely and destroyed after the report has been submitted. Supervision team and I will be the only people who will have access to this data.

Thank you for taking time to consider this invitation and if you choose to participate in this research. I would like to extend my personal gratitude; your contribution is greatly appreciated.



Paola Franshelya Reyes Veras
Research Student

Consent Form

Adopting Big Data Concepts in the Construction Industry

Consent Statement

- I agree to participate in the above research project and give my consent freely.
- I understand that the project will be conducted as described in the "Information Sheet", a copy of which I have retained.
- I understand that I can withdraw from the project at any time and that I do not have to give a reason for withdrawing.
- I consent to participate in an interview with the researcher.
- I understand that my personal information will remain confidential.
- I understand that my organisation will not be identified, either directly or indirectly.
- I have had the opportunity to have my questions answered to my satisfaction.

Print Name: _____

Signature: _____

Date: _____

Email Address (Optional): _____

APPENDIX C: PROTOCOL FOR THE SEMI-STRUCTURED INTERVIEWS

Interview Questions

Date:	
Time of Interview:	
Name of Organisation:	
Organisation's Industry Sector:	

General Information	
Name of the Interviewee	
Position of the Interviewee	
Years of Experience in the Industry	
Role in the Organisation	
Organisation's total employee size	
General Knowledge of Big Data	
• Given your role in this organisation, please explain your awareness of the "Big Data" concept and its relationship with the construction industry.	
• Are you aware of the volume and variety of data produced as part of a construction project and in your organisation?	
• Do you have a protocol in place to handle the data?	
• Do you think that your organisation is committed to embedding advanced technologies to enhance construction productivity?	
• Are you aware of the benefits resulting from Big Data adoption in other industries?	
The following questions will focus on the key drivers for adopting Big Data concepts.	
• Can you describe the key drivers that have powered the adoption of Big Data in the construction industry?	
• Can you describe the key drivers that have powered the adoption of Big Data in your organisation?	
The following questions will focus on the organisations' main challenges when adopting Big Data or other smart technologies.	
• Can you describe the challenges that are currently facing in the adoption of Big Data in the construction industry?	
• From your position in this organisation, can you name the challenges faced when adopting Big Data?	
The following questions will focus on the strategies for Big Data adoption that have been implemented or are planned to be implemented in your organisation in the next five years.	
• Regarding the job role and responsibilities that you perform in this organisation, please describe the key strategies that allow for the adoption of Big Data concepts	
• Which strategies are currently being implemented in your organisation?	

• Which strategies will be implemented in your organisation in the next five years?
The next question will focus on the impact of Big Data on organisational competitiveness.
• Given your job role and responsibilities, kindly explain how adopting Big Data concepts has contributed or could contribute to your organisation's competitiveness.
The next question will focus on the critical success factor in the adoption of Big Data concepts in the construction industry
• What are the critical factors involved in the successful adoption of Big Data in the construction industry?
The next question will focus on the need for a guidance document for adopting Big Data in construction organisations and the wider industry
• What is your opinion about the existence of a set of guidelines or guidance document for adopting Big Data in a construction organisation and the industry?

Thank you for your views on the above questions. I would also like to thank you for the time you have dedicated to this research. If you are interested in the outcome of this research, please add your contact information to the attached consent form.

APPENDIX D: VALIDATION PROTCOL FOR THE ORGANISATION READINESS ASSESSMENT TOOL

Organisation Readiness Assessment Tool for Big Data Adoption

Validation Guide

Confidentiality

This survey is being conducted as part of a PhD research and there is no commercial benefit.
The information provided through this survey will be treated with absolute confidence. The results will only be used for the purpose of this research study and not for any other purpose. The identity of the respondents and the company/organisation they work for will remain anonymous and strictly confidential.

Important Notes

1. In this survey, there are no right or wrong answers to the questions. Select the most appropriate for each question based on your view/experience.

2. There may be questions that appear irrelevant or impertinent. However, it is necessary for this study that all questions are answered as the questionnaire is designed to achieve particular research objectives. It is hoped that it will not offend the chosen respondents in any way. If there are any questions that you are unwilling or unable to answer, skip them and continue answering the remainder of the questions.

The tool delivers a way for organisations to assess their readiness to meet the changes and their ability to adopt BD while highlighting any weaknesses. Users will be presented with a series of statements describing the qualities of their organisation and they must state whether they agree or disagree. The following linear scale was used to measure readiness:

- 1 = Strongly disagree
- 2 = Somewhat disagree
- 3 = Neither agree nor disagree
- 4 = Somewhat agree
- 5 = Strongly agree

3. In section V, the “Evaluation Protocol”, you will have the opportunity to provide feedback and share your thoughts about this tool. Please do not skip this step as it will help us to validate and check its accuracy.

Research aims and objectives.

This research aims to develop a framework for adopting Big Data concepts in the construction industry. This framework will provide guidelines for adopting concepts leading to sustainable development.

To achieve the overall aim of the research, the aim has been divided into a set of specific target objectives. The objectives of the study are:

1. To understand the benefits of BD for the DR Construction Industry.
2. To explore the understanding of the Big Data concept and its characteristics in the construction industry.
3. To investigate the drivers for implementing BD in the construction industry.
4. To explore the critical strategies for BD adoption
5. To explore the challenges of implementing BD in the construction industry.
6. To develop and validate a Big Data Readiness Assessment tool for construction organisations.
7. To develop and validate a framework for implementing BD in the construction industry.

Link to the online tool

The following link allows you to have a look at the tool in an online environment:

https://survs.com/survey/bqu2u5juka

Section I: Technology Readiness

The measurement of technology readiness refers to the capability of the organisation to make optimum use of its technical infrastructure.

The measurement units selected for the readiness tool were the essential elements highlighted in the literature and in the interviews conducted with industry professionals as part of this study. The following table presents the questionnaire related to the technology readiness evaluation.

BD Technology Readiness/Technology Resources						
	Statements	**Score**				
		1	**2**	**3**	**4**	**5**
1	**Available BD IT Infrastructure:**					
1.1	This organisation has a stable and reliable IT infrastructure (e.g., hardware, software, networking components, an operating system (OS) and method of data storage).					
1.2	This organisation has a reliable Information and Communication Technology Infrastructure (e.g., digital telephone network, mobile phones, internet capability, internet servers and fixed broadband, and others).					
1.3	This organisation has Intelligent System Competence.					
2	**Organisation's BD Technology Assimilation Capacity:**					
2.1	This organisation has an adequate understanding of BD.					
2.2	This organisation has adequate protocols to improve BD observability (i.e., the ability to collect data about program execution, the internal state of modules, and communication between the components).					
2.3	This organisation is able to embed BD at all levels.					
2.4	This organisation has adequate protocols to understand BD complexity and trialability (i.e., how easily potential adopters can explore BD).					
2.5	This organisation has adequate protocols to understand BD scalability (i.e., the ability of a hardware/software parallel system to exploit increasing computing resources effectively in the analysis of (very) large datasets).					
3	**Availability of BD Tools:**					

3.1	This organisation has advanced wireless technology to capture and transmit data.					
3.2	This organisation has a healthy data environment (e.g., a mechanism to protect data privacy and anonymity).					
3.3	This organisation has adequate security protocols for data management.					
3.4	This organisation has an adequate infrastructure for data integration and quality.					

The technology readiness factor looks into the organisation's infrastructure, if it is able to support BD processes, and if the organisation can handle other essential requirements such as complexity, scalability, and security (Srinavin, Kusonkhum et al. 2021). The overall technological readiness score was assessed by calculating the total score assigned to each statement as follows:

- 60 – 48 Organisation member strongly feels that they are ready to tackle BD's technological challenges.
- 47 – 35 Organisation member fairly feels that they are ready to tackle BD's technological challenges.
- 34 – 22 Organisation member feels, to a certain extent, that they are ready to tackle BD's technological challenges.
- < 21 Organisation member does not feel they are ready to tackle BD's technological challenges.

Section II: Organisational Readiness

Organisational readiness denotes the relationships between the inner characteristics of the company, such as its processes, systems, performance and people, all of which are essential to implement any innovation process successfully.

These measurement units were selected for the readiness tool due to the significance established during the data collection phase of this study and the literature. The following table presents the evaluation questionnaire related to organisational readiness.

Organisation Readiness							
Statements		Score					
		1	2	3	4	5	
1	**Financial Capability**						
1.1	This organisation is able to allocate adequate financial resources to adopt/maintain BD infrastructure.						
1.2	This organisation has confidence in their financial readiness to adopt BD.						
1.3	This organisation believes that the perceived cost of BD adoption is affordable.						
1.4	This organisation has done its research and has the resources to adopt BD.						
2	**Culture Readiness**						
2.1	This organisation has a digitally driven organisational culture.						
2.2	This organisation has a well-established security culture.						
2.3	This organisation has adequate IT expertise.						
2.4	This organisation has a digital innovation business strategy orientation.						
2.5	This organisation has an adequate need for change readiness.						
2.6	This organisation has an efficient decision-making culture.						
2.7	This organisation has a low/non-existent resistance to change.						
3	**Leadership**						
3.1	The top management supports innovation initiatives.						
3.2	Leaders have a positive attitude towards change.						

3.3	Management supports and encourages the use of BD.					
4	**Staff Capability**					
4.1	The staff has advanced e-skills.					
4.2	The staff has adequate and up-to-date BD knowledge/skills.					
4.3	The staff clearly understand the benefits of using BD in construction projects.					
4.4	Staff have the technological capability to contribute to the BD environment (e.g., data management protocols).					
4.5	Staff is provided with training where they can develop familiarity with BD tools.					
4.6	Staff is aware of cyber threats and how to deal with them.					
4.7	Human resources promote learning and iterative improvement as well as risk-taking.					

The organisational readiness section measures the organisation's internal capability of adopting BD, from finance to culture and other resources. It assesses the elements that must be present to achieve successful implementation. The overall organisational score was determined by calculating the total score assigned to each statement as follows:

- 105 – 84 Organisation member strongly feels that they have the necessary skills and knowledge to execute the tasks and activities associated with BD implementation.
- 83 – 104 Organisation member feels they fairly have the necessary skills and knowledge to execute the tasks and activities associated with BD implementation.
- 104 – 82 Organisation member feels, to a certain extent, that they have the necessary skills and knowledge to execute the tasks and activities associated with BD implementation.
- < 81 Organisation member feels that they don't have the necessary skills and knowledge to execute the tasks and activities associated with BD implementation.

Section III: Environment Readiness

Environmental readiness refers to the organisation's interaction with its external influencers, such as its suppliers, customers, industry, and the government which will positively or negatively impact the organisation's ability to embrace innovations.

As in the previous sections, the units of measurement for environmental readiness were selected based on their recognition in the literature and the primary data analysis. In the same way, the following table presents the questionnaire related to the organisational readiness evaluation.

Environment Readiness							
Statements		Score					
		1	2	3	4	5	
1	**Supplier Interaction**						
1.1	This organisation has a good relationship with IT suppliers to facilitate BD innovations.						
1.2	This organisation keeps up to date with new digital developments.						
1.3	This organisation seeks support from IT experts to understand how to apply any new tools and software best.						
2	**Customer Interaction**						
2.1	This organisation responds to customer pressure.						
2.2	This organisation offers digitally innovative solutions to customers.						
2.3	This organisation uses technology to improve information flow with customers.						
3	**Industry Interaction**						
3.1	This organisation understands and is prepared to deal with market turbulence.						
3.2	This organisation has an adequate marketing and inventory management system.						
3.3	This organisation recognises competitive pressure as a drive for BD adoption.						
3.4	This organisation has adequate (digitalised) supply chain connectivity (e.g., orders, tracking, inventory levels).						
4	**Government Interaction**						

4.1	This organisation responds to innovative government policies.					
4.2	This organisation engages with government bodies to support BD adoption.					
4.3	This organisation engages and interacts with government agencies to improve the regulation of new technologies.					

The environment readiness section measures the organisation's response to the external elements that influence its capability to adopt BD. The interactions between the organisation and its suppliers, customers, industry, and government were identified as a critical success factor for BD adoption in both the primary data collection and literature. The overall organisational score was determined by calculating the total score assigned to each statement as follows:

- 65 -52 The organisation member strongly feels that the organisation's interaction with its external environment supports the adoption of BD.
- 51 – 38 The organisation member fairly feels that the organisation's interaction with its external environment supports the adoption of BD.
- 37 – 24 The organisation member feels, to a certain extent, that the organisation's interaction with its external environment supports the adoption of BD.
- < 23 The organisation member does not feel that the organisation's interaction with its external environment supports the adoption of BD.

Section IV: Organisation's Global Readiness Score

To assess an organisation's Big Data readiness, a representative sample from said organisation has to complete the questionnaire and respond to the statements in each context. After all of the questions have been answered, the final score for the employees' perception of their organisation's readiness to adopt Big Data was obtained by adding the scores together from all three sections. The overall score for BD readiness can be classified as follows:

- **230 – 184** The organisation is as ready as possible to adopt Big Data.
- **183 – 137** The organisation is mostly ready to adopt Big Data.
- **136 – 90** The organisation is partially ready to adopt Big Data.
- **< 89** The organisation is not prepared to adopt Big Data.

APPENDIX E: FRAMEWORK VALIDATION GUIDE

Integrated Framework for Big Data Adoption in the Construction Industry

Validation Guide

Purpose of the interview

This interview aims to validate the development of an Organisation's Readiness Assessment Tool for Big Data adoption.

Confidentiality

This survey is being conducted as part of a PhD research and there is no commercial benefit.

The information provided through this survey will be treated with absolute confidence. The results will only be used for the purpose of this research study and not for any other purpose. The identity of the respondents and that of the company/organisation they work for will remain anonymous and strictly confidential.

Important Notes

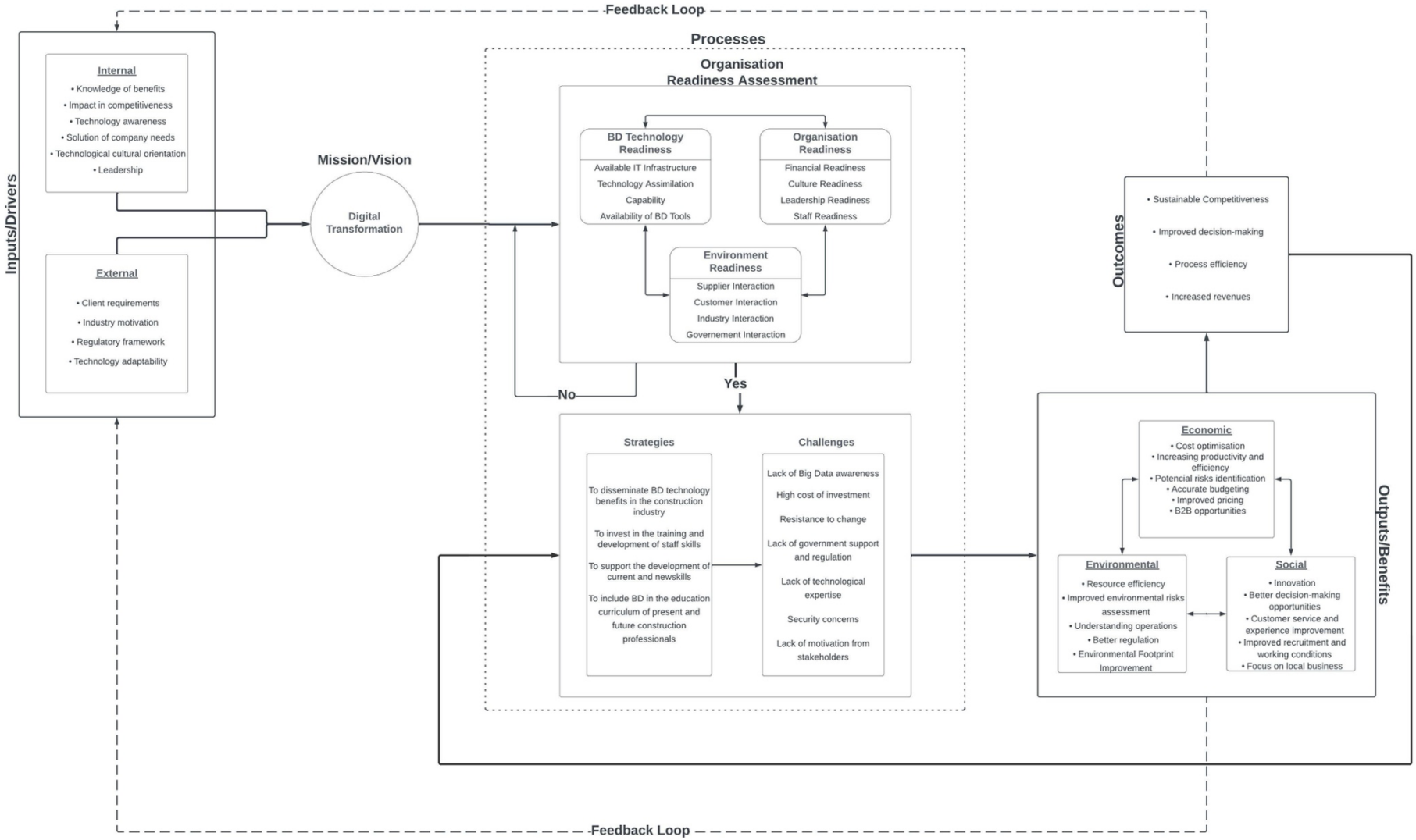
1. This survey has no right or wrong answers to the questions. Select the most appropriate for each question based on your view/experience.

2. There may be questions that appear irrelevant or impertinent. However, it is necessary for this study that all questions are answered as the questionnaire is designed to achieve the particular research objectives. It is hoped that it will not offend the respondents in any way. If there are any questions that you are unwilling or unable to answer, skip them and continue answering the remainder of the questions.

The framework is based on a combination of the literature review and this study's previous findings. This tool is aimed at organisations in the construction industry that are looking to improve their processes through digital transformation and the adoption of BD, including those that have already started this process.

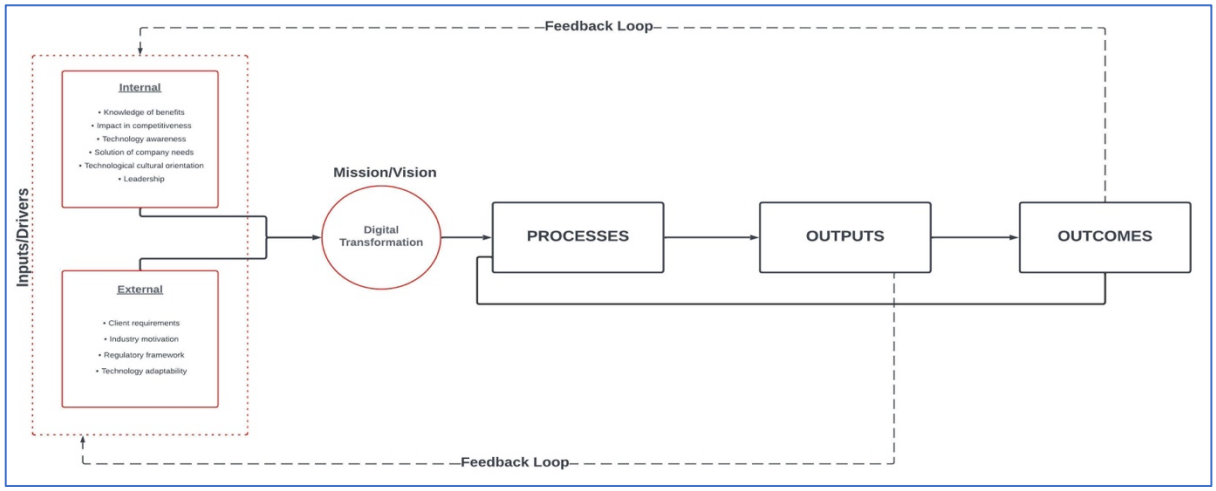
3. In section 3 of this form, you will have the opportunity to provide feedback and share your thoughts about this framework. Please do not skip this step as it will help validate and check its accuracy.

An Integrated Framework for Big Data Adoption in the Construction Industry



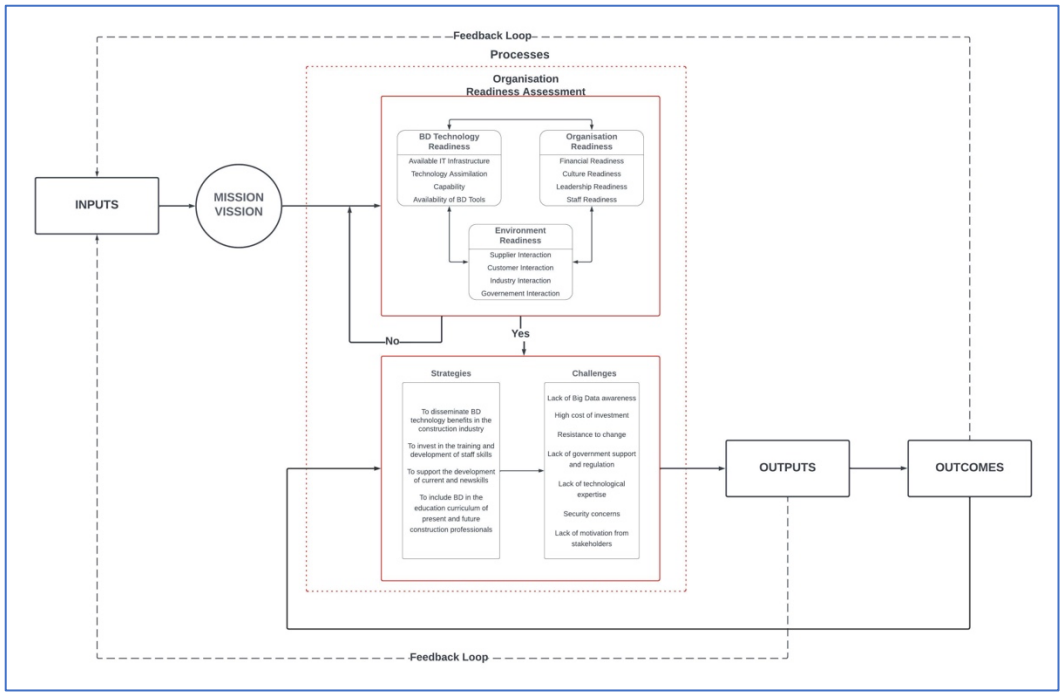
The proposed framework depicts the relationship between the drivers as shown in the figure below. Nine drivers were identified as critical factors pushing for BD adoption in the construction organisations.

Input Section of the Proposed Framework

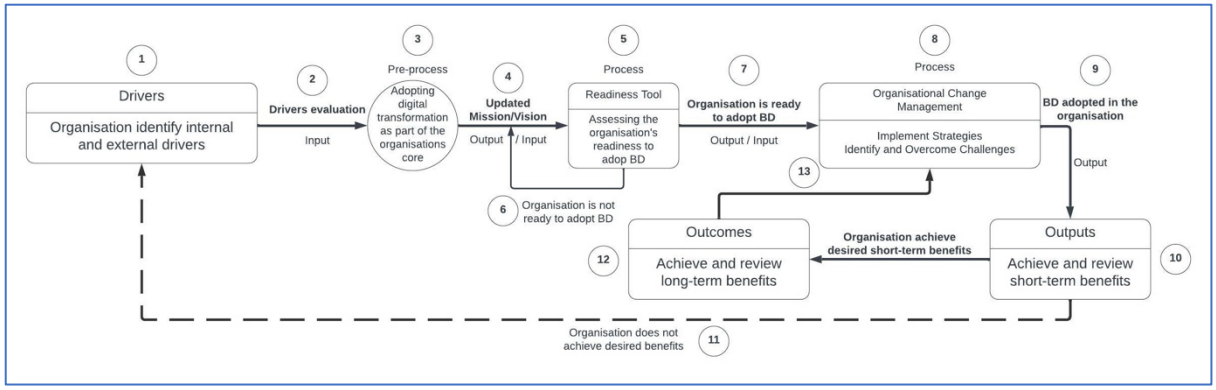


After examining and assessing the forces driving the organisation toward BD adoption, decision-makers are able to consider and develop the processes needed to achieve this goal. The second stage of the proposed framework is the “processes.” This represents the process of transformation that the organisation must undergo to reach the set goal of BD implementation in this case. This stage is comprised of three sections: mission and vision, organisation readiness assessment, and organisational change management.

Process Section of the Proposed Framework



The proposed framework contains elements that explain the sub-process flow between the components of the processes stage. This serves as a guide to enable decision-makers to navigate and explore the actions they must take to achieve the ultimate goal of BD adoption. At first glance, the path to follow might seem linear but in reality, the sub-processes can be recurrent or happen simultaneously. Therefore, the approach to consulting this section is presented in the figure below:



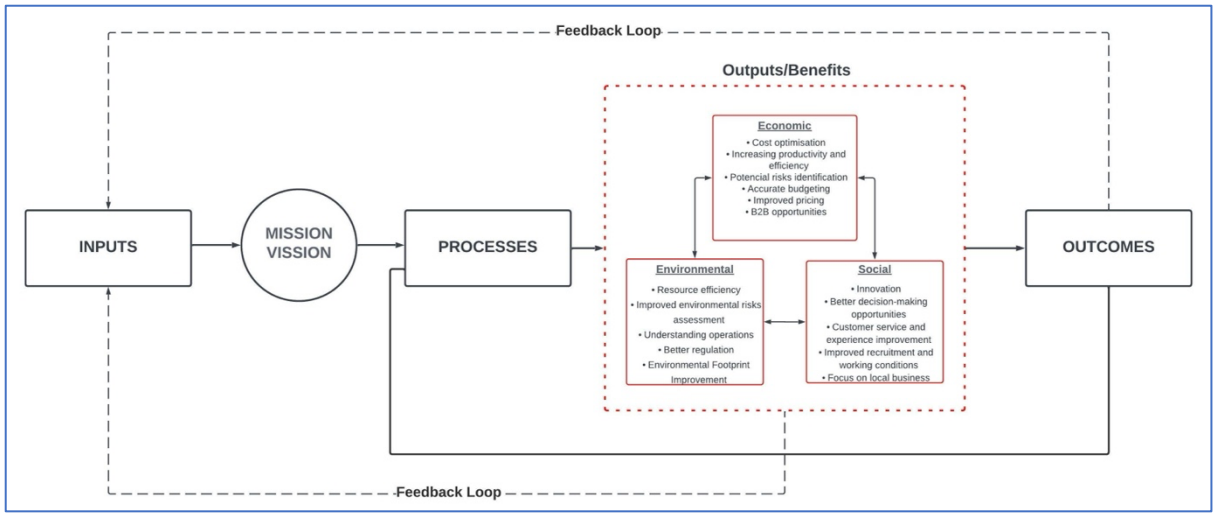
1. Organisation identifies the internal and external drivers.
2. Evaluate the internal and external drivers of the organisation. These will serve as the input for adopting digital transformation as part of the organisation's mission and vision.

3. Adopting digital transformation as part of the organisation's mission and vision will allow for a procedure migration from analogue to digital and prepare the organisation to adopt BD and other technologies.
4. Embedding DT into the organisation's culture will prepare the mindset to implement the necessary changes for BD adoption.
5. The readiness assessment process will allow for an understanding of the organisation's capability to adopt BD and what things are still needed to be able to achieve this goal.
6. If the assessment shows that the organisation is not ready to adopt BD, the drivers must be re-evaluated, the missing requirements must be addressed, and the process should start once again until achieving a different result.
7. The organisational change management process can begin when the assessment shows that the organisation is ready to make the change.
8. The organisational change management (OCM) process will guide the decision-makers in adopting BD by identifying the strategies to be implemented and the challenges to be overcome to successfully implement the technology.
9. BD is successfully adopted in the organisation.
10. Organisation has perceived and reviewed the short-term benefits.
11. If the organisation does not achieve desired short-term benefits, they must refer to the identified drivers.
12. If the organisation achieves the short-term benefits, it is on track to achieve the long-term benefits.
13. Is the organisation does not achieve the desired outcomes, it must refer back to the proposed strategies.

The third stage of this proposed framework is the outputs resulting from the BD adoption process. They represent the improvement in performance and the other intermediate benefits of BD adoption.

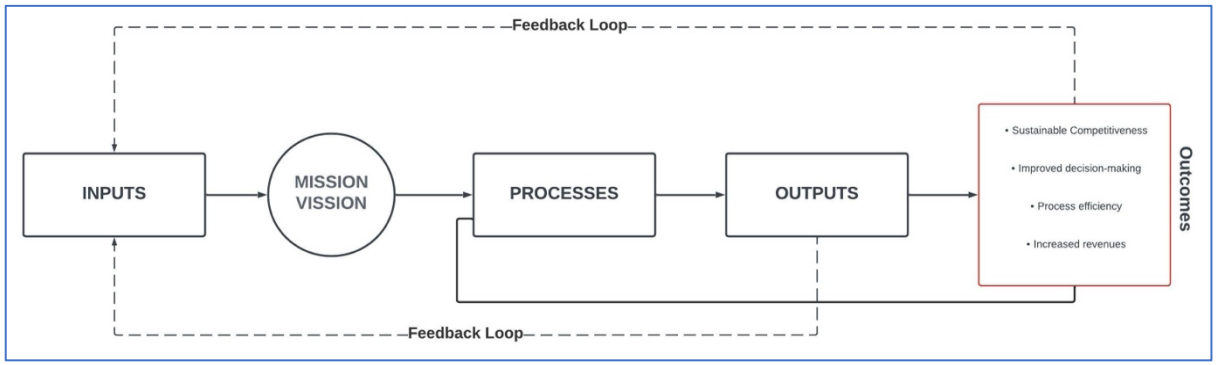
Moreover, this framework stage can be used to measure the level of success of the BD adoption process. This stage involves the variables grouped into three main outputs, namely economic performance, environmental performance, and social performance, as shown in the following figure.

Output Section of the Proposed Framework



The final stage of the proposed framework is the outcomes. This section represents the impact on the organisation's long-term performance based on the improved economic, environmental, and social areas presented in the previous section. The portrayed outputs are the long-term impact of the increased performance due to the adoption of BD in construction organisations. This study identified five long-term benefits: improved decision-making, process efficiency, increased revenues, competitive advantage, and sustainable development, as shown in the following figure.

Outcomes Section of the Proposed Framework



As with the previous section, the identified outcomes must be monitored and evaluated following the same process as before, specifically feeding the results into the early stages of the process until the desired effects are achieved.

Integrated Framework for Big Data Adoption in the Construction Industry

Validation Protocol

This validation protocol aims to refine and validate the developed framework regarding the clarity, information flow and contents in terms of both the generic and detailed components. This framework is part of a doctoral research study that has sought to develop an integrated framework to assist construction organisations in adopting Big Data Technology. The developed framework for BD adoption is based on the findings of the literature review and 21 semi-structured interviews.

This protocol aims to gather your responses which will help the researcher to validate the tool that will subsequently be applied in the effective Big Data adoption initiatives within the Dominican Republic's construction industry. This cannot be successfully achieved without your participation. You are therefore requested to provide your feedback. This process is estimated to take about 15 minutes.

To protect your confidentiality, privacy, dignity and anonymity, your answers will be attached to a unique code that will only be understood and accessed by the researcher. The information will be stored on a password-protected computer so then only the researcher has access. Finally, your data will be destroyed once the degree is achieved. The project has ethical approval for the study protocol from the University of Wolverhampton, which provides ongoing assurance.

Research aims and objectives

This research aims to develop a framework for adopting Big Data concepts in the construction industry. This framework will provide guidelines for adopting the concepts leading to sustainable development. To achieve this aim, the following objectives have been identified.

1. To understand the benefits of BD for the DR Construction Industry.
2. To explore the understanding of the Big Data Concept and its characteristics in the Construction Industry.
3. To investigate the drivers for implementing BD in the construction industry.
4. To explore critical strategies for BD adoption
5. To explore the challenges when implementing BD in the construction industry.
6. To develop and validate a Big Data Readiness Assessment tool for construction organisations
7. To develop and validate a framework for implementing BD in the construction industry.

Questions:

- What is your opinion of the level of understanding of the developed framework?
- What is your opinion regarding the overall completeness of the developed framework?
- What is your opinion regarding the logic flow of the developed framework?
- Do you have any further comments/suggestions regarding any areas that need to be improved/included/deleted within the developed framework?
- How would you describe the usefulness of this framework for companies in the construction industry?