BIG DATA ADOPTION IN KUNMING CONSTRUCTION INDUSTRY, THE PEOPLE'S REPUBLIC OF CHINA: AN EMPIRICAL STUDY

By
Mr. Yang DESONG

A Thesis Submitted in Partial Fulfillment of the Requirements
for Master of Engineering ENGINEERING MANAGEMENT
Department of INDUSTRIAL ENGINEERING AND MANAGEMENT
Silpakorn University
Academic Year 2023

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โดย
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By	Mr. Yang DESONG
Field of Study	ENGINEERING MANAGEMENT
Advisor	Noppakun Sangkhiew, Ph.D.

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This study investigates the current situation, benefits and drawbacks, and primary factors of adopting big data technology in Kunming's construction industry. Three instruments for investigating were innovated. The first questionnaire asked respondents about the current situation and opinions on adopting big data technology. The second one was a questionnaire asking experts in the construction industry and academic sections their opinions about the gains and losses of adopting technology. The last instrument was a semi-structured interview question about primary factors that need to promote big data technology in the construction industry.

There were three hundred twenty-seven respondents in the first section, ten respondents in the second section, and five interviewees in the last section. The result, analysis, and discussion revealed that adopting big data technology is not proliferating. The main barriers are lack of knowledge, skilled staff, and investment. It also needs to be improved to bridge the gap between construction and building management companies, chiefly by utilizing big data technology. The principal benefit of big data technology is that it facilitates procurement operations of construction projects. The data and analysis help management monitor, control, and award the parties. Please note that internet-of-thing technology is needed to boost big data technology. However, it needs a significant investment.

Lastly, building information modeling (BIM) technology is a primary factor influencing a construction project to implement big data technology. Augmented big data-building information modeling (BD-BIM) is an excellent strategy. BIM helps the adoption of big data technology successfully. Please note that this study not only helps report the situation of technology adoption but also guides the academic section to do more research on the practical framework of big data technology adoption.

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CHAPTER 1
INTRODUCTION

1.1 Motivation

According to Ngowi et al. (2015), the construction sector contributes significantly to the expansion of economies all over the world. Because it is one of the most important players in resource consumption, it has an ongoing demand for technical advancements. In contrast to the requirements of society and the environment, construction methods and materials have changed very little or not at all over the past few decades (Alaloul et al., 2018). It is because society and the environment require that projects provide experiences that are more tailored to the needs of the users while also adequately managing resources throughout all stages of development (Baker et al., 2020).

On the other hand, the sector is plagued by a number of flaws that hinder the supply of goods and services in an effective manner, which results in an annual loss of around $1.6 trillion for the global economy (Yousif et al., 2021). Some of the most important factors contributing to the downfall of the sector include obstacles such as stagnating productivity levels, health and safety concerns, an aging workforce, talent shortages, and insufficient use of technology (Atuahene et al., 2020).

Over the course of the last few years, this reluctance to change has been tested. Industry Revolution 4.0 (I4.0) and other trends and technologies, such as building information modeling (BIM), the Internet of Things (IoT), and smart devices, are creating waves in the sector and pushing for more digitization (Cabrera-Sánchez & Villarejo-Ramos, 2020). These technologies are also directly connected to Big Data (BD) in the construction industry since they are vital in providing the infrastructure for the generation of data, the transmission of data, and the storage of data (Sagiroglu & Sinanc, 2013).

Furthermore, the amount of data today is staggering, and the rapid pace of technological advancement is primarily to blame for this trend. Nowadays, corporations' data is measured in petabytes (10^{15} bytes). While Google handles more than 24 petabytes of data daily, Facebook receives more than 10 million new images every hour (Walker, 2014). In 2012, there was an increase of around 2.5 quintillion (10^{18}) bytes per day in the surplus of data. Because of the proliferation of data, scientists today have great chances to discover information and insights that can be of practical benefit. Data availability has the potential to enhance the status quo in various sectors by either enhancing the statistical and computational approaches that are already in use or even by rendering them obsolete (Bilal et al., 2016).

The widespread adoption of digital technology has not spared the building and construction sector either. Throughout the entire life cycle of a facility, the industry must deal with a substantial amount of data that originates from a variety of disciplines. Building Information Modelling, or BIM, is an ambitious project that aims to systematically record multi- dimensional CAD information in order to facilitate interdisciplinary cooperation among many stakeholders. BIM data is often encoded in a three-dimensional geometric structure, is computationally complex (including graphics and Boolean computing), is compressed, and can be found in a variety of proprietary file formats (Huang, 2021). As a result, all of these different kinds of data are compiled into federated BIM models, which are continually enriched and continue to exist after the end-of-life of respective facilities. The design data for a building model with three storeys may easily exceed 50 GB in capacity, which is one reason why BIM files can quickly balloon in size (Lin et al., 2016).

It should be noted that the performance of the industry places an inherent value on this data in any form or shape it may take. Facilities have also begun to create huge data during the operations and maintenance stage as a result of the emergence of embedded devices and sensors, which will eventually lead to additional rich sources of Big BIM Data. The construction industry has been forced to embrace the era of big data as a result of the massive accumulation of BIM data (Atuahene et al. 2020).

Over the past seven decades, Kunming, the capital city of Yunnan Province in southwest China, has seen fast economic and social growth (Wenxin, 2019). As a result, the city has gradually transformed into a regional international hub. She has been actively contributing to the building of the Belt and Road by consistently expanding its opening up. The city has developed commercial links with 203 nations and territories, enticing 98 of the World's Top 500 corporations to invest there. The total amount of the city's exports and imports of goods and services in 2018 was 13.12 billion dollars US (Li, 2020). From 1952 to 2018, Kunming's gross domestic product went from 156 million yuan to 520.6 billion yuan, which is a rise of 543 times. Additionally, the city's GDP per capita surpassed 10,000 United States dollars. The general budgetary revenue of the city rose by 162.7 times from 366 million yuan in 1978 to 59.563 billion yuan in 2018, bringing the total to 59.563 billion yuan. The city's industrial structure has been steadily optimized, and the contribution to GDP by the primary, secondary, and tertiary industries has been adjusted from 39:34:27 in 1952 to 4.3:38.4:57.3 in 2018. This adjustment was made possible by steadily optimizing the city's industrial structure. In terms of urbanization, Kunming's metropolitan area grew from 7.8 square kilometers in 1949, the year the People's Republic of China was created, to 416 square kilometers today, representing an increase of 52.3 times. In 1978, just 29.5 percent of the city's permanent population were urban residents. Today, urban people comprise 72.9 percent of the city's permanent citizens (Lede et al., 2016).

Concerning public transportation, Kunming's urban bus network coverage rate has recently reached 79 percent, placing it second among cities in China. The total length of the city's expressways is 766 kilometers, while the mileage of the city's urban rail is 88.76 kilometers. The function of the city as a transportation hub was significantly improved in 2012 when Kunming Changshui International Airport began operations. Kunming, also known as the "Spring City," has supported environmentally responsible development and given ecological civilization much attention. The percentage of land covered by trees in the city reached 49.57 percent in 2018, and the amount of public green space available per person was three times as large as in 1952. In 2018, the water quality at Dianchi Lake, formerly one of China's most polluted lakes, improved to grade IV, making it the best it has been in the past 30 years (Wenxin, 2019).

To the best of my knowledge, there is no knowledge about BD adoption in Kunming’s construction industry. The researcher is curious about how to improve the construction industry in Kunming by deploying BD technology. Thus, the current situation and its impacts must be examined. Then, the influencing factors must be identified to promote the technology adoption.

1.2 Research Questions

Research Question 1: How does the current situation of big data technology adoption in Kunmin's construction industry?

Research Question 2: What are the benefits and drawbacks of big data technology adoption in Kunming's construction industry?

Research Question 3: What factors influence big data technology adoption in Kunming's construction industry?

1.3 Research Objectives

Straightforwardly, the research objectives are interpreted from the research questions.

1. To explore the current situation of big data technology adoption in Kunming's construction industry.

2. To pinpoint the advantages and disadvantages of big data in case of Kunming's construction industry.

3. To identify the primary factors influence big data adoption in Kunming's construction industry.

1.4 Research Contributions

1. The knowledge gap about big data adoption in Kunming's construction industry is fulfilled.

2. The big data capability is pointed out for construction industry practitioners who are interested in adopting the technology.

3. Big data applications are promoted by using guided influencing factors in this study

1.5 Scopes and Limitations

1. This study is a survey research using a questionnaire as a research tool. It means the results are based on the time and sample size of the study.

2. The data is collected between October 2023 and January 2024

3. The study area is Kunmig, Yunnan Province, the People's Republic of China.

1.6 Abbreviations

AIC	Advanced Industrialzied Country
BDA	Big Data Analytics
BDE	Big Data Engineering
BD-BIM	Big Data-Building Information Modeling
BIM	Building Informantion Modeling
ERP	Enterprise Resource Planning
GB	Gigabyte
I4.0	(the) Fourth Industrial Revolution
IPD	Integrated Project Delivery
LDC	Least Developed Country
NIC	New Industrialized Country
NoSQ	Not only Structured Query Language
NLP	Natural Language Processing
RBDMS	Relational Database Management System
RFID	Radio Frequency Indetification
SQL	Structured Query Language
TOE	Technology-Organization-Environment

CHAPTER 2
LITERATURE REVIEW

2.1 Construction Industry

2.1.1 A brief history of construction industry

In the ancient world, construction was dependent on the natural resources of the land, the climate, and the collective local skills in order to create shelter forms that reflected a precise and detailed knowledge of the local climatic conditions on the one hand and, on the other hand, a reasonable understanding of the performance characteristics of the construction materials that were available (Ngowi et. al., 2005). Stone, clay, and other materials gathered from the surrounding forests were used to build the earliest shelters and towns. These structures offered protection from the elements, including cold, wind, rain, and other forms of precipitation. The techniques that were applied in the building of these shelters with the aforementioned materials were the result of innumerable attempts, mishaps, and the accumulated knowledge of generations of builders who kept using what was successful and abandoned what was ineffective. During the early stages of community development, building was an activity in which every member of the community took part. People took part in every stage, from the planning to the manufacturing, and they were able to include both their beliefs and themselves in the final product so that it accurately reflected their cultures. Figure 2.1 illustrates an example of an ancient shelter.

Figure 2.1 Acient world’s shelter.
Source: Sjoberg (2014)

Conquests were a typical occurrence in early societies. During these conflicts, groups would battle one another, and the members of the community that was defeated would be seized as prisoners by the community that was victorious. In many cases, the conquerors took control of the economic operations of the communities they had destroyed. With this power, they were able to utilize the ensuing funds, in addition to their own, to substitute the vanquished community's infrastructure with one of their own design. This phenomenon may be seen all across the record of European history. For instance, the structures that were used in the early Greek villages that were located around the Mediterranean were made of mud and were framed with timber. In later times, temples and theaters were constructed out of marble. However, the Romans, who were responsible for the establishment of the Roman Empire, not only conquered these towns but also affected not only the methods of construction but also the whole culture of the people. The Roman Empire, which had its capital in Rome, included an area that is today known as Great Britain all the way to the Middle East. At its height, between the 2nd and 1st centuries BC, the Roman Empire was home to between 60 and 100 million people. The Romans had an impressive infrastructure, and the majority of their structures were constructed out of stone and marble. Marcus Vitruvius Pollo penned the world's first substantial publication on architecture and construction during the time of the Roman Empire. In it, he discussed topics like as building materials, the style, and design of various types of buildings, the method of construction, building physics, astronomy, and building machinery. This book was the first of its kind in the history of the world. Vitruvius provided a description of the hypocaust, which was the heating system that was utilized in the public baths as well as the homes of prominent officials and wealthy individuals, among other specifics. The hypocaust, which was first developed in the 1st century BC, was comprised of a suspended floor that was held up by columns and heated by hot gases that were created by a furnace at one end and expelled by a chimney at the other. After the downfall of the Roman Empire in 476, which was marked by the fall of Rome, construction and architecture came to a standstill for several centuries. The Romans were responsible for ushering in a beautiful new chapter in architecture and construction. Participation in various aspects of building during this time period was the primary means by which construction expertise was transmitted from one generation to the next (Kim, 2010).

The years that followed the fall of the Roman Empire are referred to as the "Middle Ages," and they span from 476 to 1492. Despite the fact that there were less construction operations taking place there, it was a witness to the building of beautiful churches and other architectural marvels, such as those in Pisa. During this time period, there was an increase in the level of organization seen in the construction industry, namely in the processes of cutting down trees, quarrying stone, firing bricks and tiles, and burning lime for cathedrals and other buildings. Craft training and education ultimately resulted in an increase in the status of craftsmen, which was one of the most significant improvements brought about by the social stability of the Middle Ages in relation to the construction operations that took place during this time. The construction of buildings became a key industry (Spufford, 1988), and as was the case in other industries, the establishment of guilds led to the development of a more organized approach to building construction. Craft guilds were professional organizations in Europe that served to protect and regulate craftspeople in a particular line of activity. These organizations were known as "guilds." Their qualities were, for the most part, same across Europe. The guilds were structured as hierarchical organizations, with members often falling into one of three distinct categories: masters, journeymen, or apprentices. The master mason was dedicated to the completion of the structure on which he was working. Not only did he design it and direct its building, but in many cases he also lived on the site, so his contributions were extensive (Linder, 1994).

The period known as the "Renaissance" came after the "Middle Ages," and it was characterized by a rebirth in the fields of architecture, construction, and science. It was denoted by the introduction of another ambitious and exhaustive publication, which was a set of four volumes on architecture written by the Italian Andrea Palladio and released in the year 1570 (Goldberg & Griffey, 2019). It gave birth to a brand new Palladian aesthetic. However, during this time period, novel approaches to building began to displace the old monopoly held by the medieval construction guilds. It was a result of the spread of new building techniques. Craft organisations were outlawed by decrees and acts, and finally, the fall of the guilds led to the development of professional designers and contractors. In broad strokes, this time period is significant because it marks the transition of the building industry from a series of disorganized activity to a more structured one. Figure 2.2 shows the architech style of Palladian aesthetic.

Figure 2.2 Palladio's architecture.
Source: Zeiba (2019)

2.1.2 Constructions in industrialization

The Industrial Revolution began in the 18th century and ushered in a period of substantial technological advancement in the manufacturing sector. During this period, there was only a small amount of innovation in the construction industry. Despite this, significant advancements were made in construction materials during the 19th century. In particular, the development of cast iron, wrought iron, and later steel made it possible to build new structures such as railways, bridges, and building frames. Additionally, glass was utilized for steel-framed buildings that featured large glazed envelopes, and Portland cement led to the creation of concrete and later reinforced concrete structures. A new industrial sector that produced building equipment (elevators, boilers, radiators, pipelines, and sanitary appliances) appeared at the end of the 19th century.

The proliferation of building materials during the industrial revolution and the increased need for housing in Europe during World Wars I and II, especially the latter conflict, laid the groundwork for advancing more efficient construction technology. The transition from conventional labor-intensive techniques to contemporary technologies, commonly known as the industrialization of buildings, was imperative. Various definitions of construction industrialization have been proposed. According to Sebestyén (2003), the industrialization of construction involves the implementation of novel technologies, such as prefabrication, and the adoption of contemporary in situ processes, such as slip-forms for structures like chimneys, bunkers, and silos. Additionally, it encompasses the utilization of advanced framework systems like tunnel shutters and pre- stressing methods. Moreover, industrialization is additionally distinguished by the use of contemporary design methodologies that include scientific insights pertaining to structures, building physics, fire safety, and computer technologies.

Prefabrication, as a manifestation of industrialization, entails manufacturing building components in an industrial setting, either off-site or close to the construction site. Timber has historically served as a fundamental material and continues to do so. However, the practice of pre- cutting stones has also been seen. In contemporary times, prefabrication has extended to encompass many structural materials such as timber, steel, aluminum, concrete, and polymers. The utilization of prefabrication techniques has shown to be effective in producing residential houses and multi-story industrial structures, commonly referred to as portal houses, mobile homes, manufactured housing, and system construction, among other terms. The advent of concrete brought about a renewed momentum for prefabrication, not only in the realm of houses but also in the construction of civil engineering constructions like bridges.

Nevertheless, the approach has not been immune to criticism, as Goodacre (1983) noted, who argues that the building systems notion is often perceived as a cure-all solution by architects, administrators, and politicians. However, in reality, it has little value. The concept of "prefabrication" lost favor in the United Kingdom while remaining popular in other nations such as the United States, France, and Scandinavia. In summary, prefabrication has historically been employed as a construction approach when challenging local conditions exist. During the late 19th Century, the British exhibited a practice of dispatching prefabricated housing to both Australia and Africa. Notably, in the 1830s, the Manning 'Portable Colonial Cottage for Emigrants' emerged as a prominent example of such housing, capable of being swiftly built within hours. This model was manufactured and transported globally to many locations.

Mechanization, as an alternative mode of industrialization, holds significant relevance in building, serving as a pivotal catalyst for technical progress. The steam engine had little utility in construction, but the introduction of the internal combustion engine (gasoline and oil) and the electric motor revolutionized this field (Sexton, 1995). Initially, the operative components of construction machinery, including excavators, scrapers, graders, and bulldozers, were propelled by ropes. However, these ropes have since been substituted by mechanical, hydraulic, pneumatic, or electrical mechanisms, individually or in combination. Various sizes and capabilities of construction machines have been designed to cater to diverse task requirements. In several sectors of extensive building projects, including open mining operations, specialized machinery has been developed to accommodate the demands of large-scale operations. The industrialized nations, sometimes referred to as AICs, have a robust industrial sector encompassing construction machinery production. Companies such as Caterpillar, Deere, and Komatsu are involved in producing heavy gear specifically designed for the construction sector, including excavators and tower cranes.

Additionally, several companies within this industry are involved in the manufacturing of substantial machinery utilized in the fields of agriculture and mining. Following significant advancements in the utilization of machinery, the construction sector has initiated efforts toward integrating robotic technology. The utilization of robots in various construction operations is on the rise. These operations include excavation and transportation, slip-form procedures, tunneling, and underwater work. The AICs have gained a competitive edge in the worldwide market because of their capacity to manufacture construction machinery, one of the four essential sectors in the construction industry. These sectors include contracting, consulting, building materials production, and construction machinery manufacturing (Peurifoy & Ledbetter, 1985).

2.2 Industrial Revolution 4.0

2.2.1 Industrial revolution's background

The introduction of the steam engine in 1760 was the catalyst for the beginning of the first industrial revolution. The steam engine made it possible for people to move away from subsistence farming and feudal societies and toward more modern methods of production. Coal was the primary source of energy throughout this shift, and railways were the predominant mode of transportation. In terms of employment, the value of production, and the amount of capital spending, the textile and steel sectors were the most prominent. In the year 1900, the internal combustion engine was invented, and this marked the beginning of the second industrial revolution. This ultimately resulted in an age of rapid industrialization, during which mass manufacturing was powered by oil and electricity. The year 1960 marked the beginning of the beginning of the third industrial revolution, which was defined by the application of electronics and information technology in order to automate manufacturing. (Berg & Hudson, 1992) The traditional method of putting things together consisted of screwing or welding a large number of components together. The first three waves of the industrial revolution may be seen in Table 2.1, which covers the years 1760 to 2000.

Table 2.1 Main characteristics of industrial revolutions.

Period	Transition Period	Energy Resource	Main Technical Achievement	Main Developed Industries	Transport Means
I: 1760-1900	1860-1900	Coal	Steam Engine	Textile, Steel	Train
II: 190-1960	1940-1960	Oil, Electricity	Internal Combustion Engeine	Metallurgy, Auto, Machine Building	Train, Car
III: 1960-2000	1980-2000	Nuclear Energy, Natural Gas	Computers, Robots	Auto, Chemistry	Car, Plane

Source: Xu et al. (2018)

2.2.2 The fourth industrial revolution and its applicaitons

The inaugural presentation of the fundamental principles of the Fourth Industrial Revolution (I4.0) was documented in 2011, as seen in Fig. 2.3. The following technology will have a transformative and irreversible impact on the sector, surpassing the rate of change observed in its three preceding iterations. Despite the considerable focus on understanding Industry 4.0 on a global scale, there still needs to be a universally accepted formal definition. Nevertheless, it may be characterized as the amalgamation of intricate physical equipment and gadgets alongside networked sensors and software used to forecast, regulate, and strategize for improved commercial and societal results. Alternatively, it can be described as a novel value chain arrangement and administration across the whole lifespan of items. Table 2.2 is an extended of Table 2.x by describe the fourth industrial revolution details.

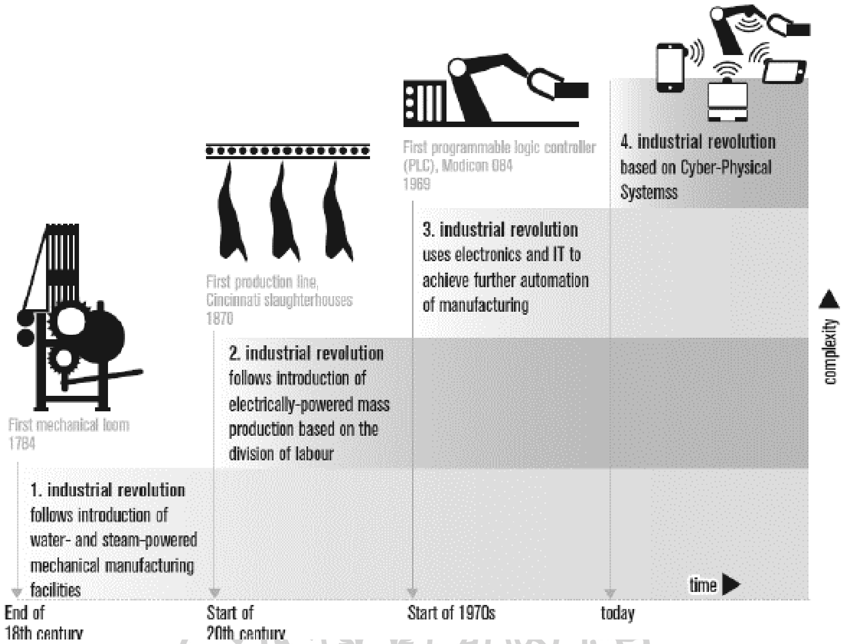

Figure 2.3 The stages of industrial revolution.

Source: Alaloul et al. (2018)

Table 2.2 The characteristics of I4.0.

Period	Transition Period	Energy Resource	Main Technical Achievement	Main Developed Industries	Transport Means
IV: 2000-	2000-2010	Green Energies	Internet, 3D Printer, Genetic Engineering	High Tech Industries	Electric Car, Ultra-Fast Train

Source: Xu et al. (2018)

According to Xu et al. (2018), the current phase of the fourth industrial revolution encompasses computer-generated product design and three-dimensional (3D) printing, a process that includes the construction of solid objects by layering materials. A Fourth Industrial Revolution is emerging, an extension of the Third Industrial Revolution, also known as the digital revolution, that has been unfolding since the mid-20th century. The phenomenon under consideration is distinguished by the amalgamation of many technologies, gradually eroding boundaries between physicality, digitality, and biology.

Three factors differentiate the current transformations from the Third Industrial Revolution, signifying the emergence of a unique Fourth Industrial Revolution. These factors include the speed at which changes occur, the breadth of their influence, and their impact on many systems. The velocity at which contemporary advancements are occurring is unparalleled in historical context. In contrast to preceding industrial revolutions, the Fourth Industrial Revolution is characterized by a rapid rate of evolution that follows an exponential trajectory rather than a linear one. Furthermore, it is causing significant disruptions across many industries in virtually all nations. According to McDonough and Braungart (2017), these modifications' extensive scope and profound nature signify the imminent overhaul of whole frameworks pertaining to production, management, and governance.

2.2.3 Construction industry and industrial revolution

The construction industry exerts a significant impact not just on the economy but also on the surrounding environment and broader society. The built environment, encompassing houses, businesses, and transportation systems, has a significant role in shaping individuals' daily lives across several dimensions. Construction projects are increasingly getting more intricate, with escalating financial and scheduling demands, as well as expanded possibilities for achieving higher-quality outcomes. When juxtaposed with several other industries, it is evident that the construction sector frequently lags behind in terms of technological progress. Consequently, the advancements achieved in the field have shown to be inadequate, exhibiting a consistent degree of stagnation during the preceding five decades. Personnel within the construction sector largely depend on specialized talents, specific training, technical proficiency, and experiential judgment. These elements are particularly challenging to automate owing to their intrinsic human nature (Alaloul et al., 2018).

Recent research indicates that the construction industry has struggled to match the productivity gains shown in the industrial sector over the previous two decades (Hinings et al., 2018). The disparity in magnitude between the construction industry and the manufacturing sector is predominantly noteworthy. In comparison to the average productivity growth rate of 27.1% observed across various industries over the previous decade, the manufacturing sector has had a notable increase of 34.1% in its production levels (Alaloul et al., 2018). Although the construction sector and the manufacturing industry are categorized as separate entities, they exhibit significant interdependence. When examined from the perspective of construction industrialization, the building and construction industry can be seen as an exemplary illustration of the manufacturing sector. The evaluation of digitization's potential in the construction industry may be conducted by examining its impact on various divisions, departments, and functions. Additionally, this potential can be categorized into four main areas: digital data, digital access, automation, and connection. The phrase "digital data" pertains to the electronic acquisition and manipulation of data, aiming to get novel and up-to-date insights into each aspect of the value chain and afterward applying these enhanced insights in a more efficient manner (Perkins & Skitmore, 2015). The automation cluster comprises a variety of innovative technologies that are accountable for the creation of autonomous and self-organizing systems. The concept of ‘digital access’ pertains to the theoretical capacity for a mobile device to establish connectivity with the internet and local networks. In summary, the concept of connection demonstrates the capacity to establish links and facilitate the coordination of actions that were previously conducted in isolation. The value chain may be analyzed by considering the following relationships in terms of their significance to the many stakeholders in the construction sector: Within the realm of construction endeavors, the financial resources designated for the acquisition of goods and services, as well as the necessary materials, constitute a significant proportion of the overall budgetary allocation. The assistance offered by digital platforms contributes to the maintenance of a reduced budget. The utilization of electronic procurement can result in a budget reduction of roughly 5% for paper-based rebuying and around 10% for online auctions (Newman et al., 2021).

2.3 Big Data Technology

The establishment of a precise and universally accepted definition for big data has emerged as a significant obstacle, mostly because to varying interpretations. The idea of big data encompasses two primary components at a metalevel: the inherent features of the data itself, and the corresponding technology required for its storage and processing. There exists a general agreement about the technological aspect, whereas differing opinions persist regarding the defining properties of data that constitute big data. The definition proposed by Atuahene et al. (2020) has been used for this study due to its comprehensive portrayal of big data and its widespread recognition in scholarly discourse.

> “the collection and interpretation of massive data sets made possible by vast computing power that monitors a variety of digital streams - such as sensors, marketplace interactions and social information exchanges - and analyse them using ‘smart’ algorithms.”

The data management life cycle may be further subdivided into three stages, each of which is comprised of the aforementioned two major components. The first stage of the data management life cycle consists of identifying the sources of big data. The second stage of the data management life cycle involves storing, processing, and analyzing large data.

Big data sources: The features of big data are related to the different sources of data and storage, as indicated in Figure 2.4. Kitchin (2013) distinguished between three types of sources for big data: directed, automated, and voluntary. According to Han and Golparvar-Fard (2017), the directed sources come from "digital forms of surveillance," which include construction-related technologies such as drones and time-lapse cameras, among other things. The digital devices, machines, sensors, and actuators that are incorporated within things like phones, smart wearables, and RFIDs are what create the automated data. According to research carried out by Kanjanabootra et al. (2019), the data that was gathered through crowdsourcing and data that was made public on social media platforms are considered to be examples of volunteered information. While the traditionalists (Russom, 2011; Davenport, 2014; Bilal et al., 2016; Han and Golparvar-Fard, 2017) - a term for some researchers in the context of this study - consider the characteristics of data to be 3Vs, therefore large amounts (volume) of heterogeneous (variety) datasets, generated at a faster speed (velocity), the progressives (Demchenko et al., 2013; W The data capture technologies, the frequency and rate of usage, as well as the safety of the data all have a role in determining the characteristics of the data.

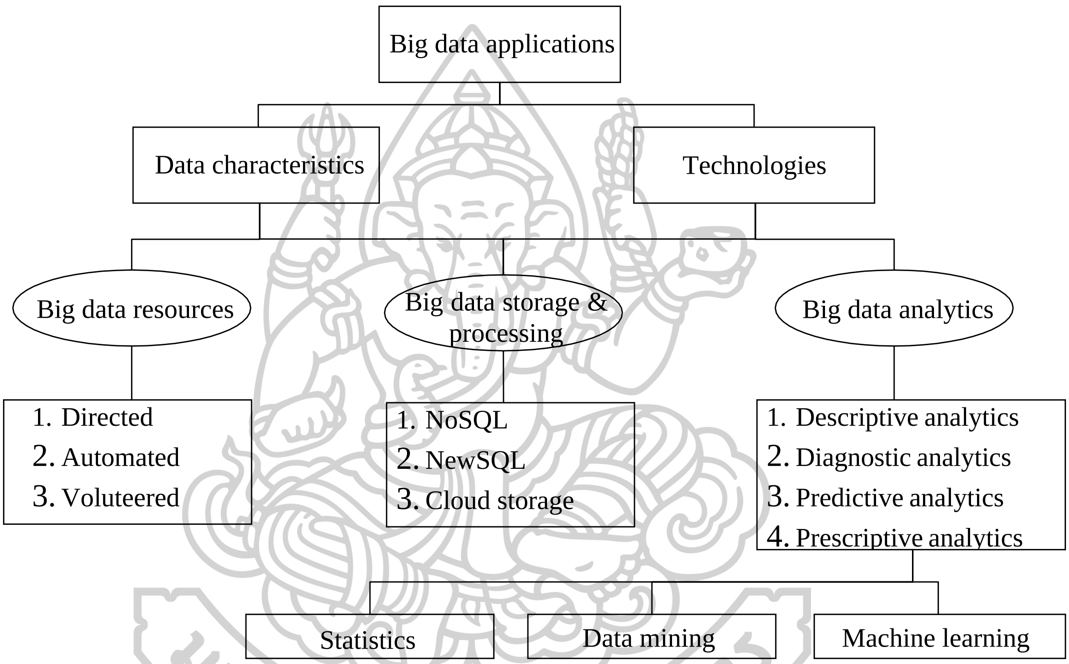

Figure 2.4 Big data beakdown structure.
Source: Atuahene et al. (2020)

Storage and processing of big data: This involves the administration of the data through the use of Hadoop Map/Reduce and Spark, in addition to the storage of the data either through the cloud server or a conventional storage device. The collection of data in its many formats requires the use of storage and management strategies that are uniquely tailored to meet their requirements. According to Strahbach et al. (2016), there is a broad variety of cutting-edge technology that may be used to store and handle many different kinds of data, including the following types of information: A distributed database known as NoSQL (which stands for "Not only Structured Query Language") is an alternative to the relational database management system (RDBMS) that is designed to manage a wide variety of data types and perform well at the same processing time in the event that there is an increase in workload (scalability). NewSQL is a new relational database management system (RDBMS) that combines the benefits of scalability offered by NoSQL with the rigorous consistency provided by traditional RDBMS. Cloud storage has gained increasing significance in today's world as a result of the enormous volumes of data that are created, transferred, and used on a regular basis.

Analytics for large amounts of data: Depending on the level of analytics, the analytics process and evaluate the data by providing management with insights that assist management in making decisions. The analysis of large amounts of data may be subdivided into the following categories: descriptive, diagnostic, predictive, and prescriptive analytics. These levels provide an understanding of what is taking place, why it took place, what is anticipated to take place, and what should be done in response to the data surrounding what is taking place. Acquiring these insights may be facilitated by the performance of activities such as machine learning, Natural Language Processing (NLP), Business Intelligence, or Cloud Computing. For construction practitioners to be able to do those analyses, they need to receive training as data scientists. However, construction practitioners may be educated to build knowledge in the life cycle concepts of big data, which are fundamental to the execution of their jobs, such as the acquisition of data and the application of the data. This can be accomplished through training.

2.4 Big Data in Construction Industry

The building and construction sector is plagued by inefficiency, poor performance of workers, and difficulties in making effective use of resources. Because of this circumstance, there has been a focused effort made to incorporate technologies such as BIM, big data, and data analytics in order to increase productivity and boost efficiency in the planning, design, and overall delivery of construction projects. These technologies aim to improve productivity and promote efficiencies in the construction industry (Ram et al., 2019).

Adoption of big data is essential to attaining construction efficiency since it might make data mining and the discovery of new insights easier. These new insights could include a knowledge of the elements that cause work delays. Researchers Bilal et al. (2016) are in agreement that knowledge discovery in databases may rapidly examine large data sets pertaining to construction in order to determine the factors that contribute to construction delays, cost overruns, and quality controls. Big data makes it possible to analyze massive data sets, which improves both the accuracy of early-stage construction project estimations and the overall cycle time that can be predicted for construction activities.

According to the findings of Mawed and Al-Hajj (2017), Big data helped increase performance in facility management and permitted change in business and operation models, which facilitated informed, more intelligent, and speedy decision-making. Adopting BD results in an organization gaining capabilities that can be leveraged to build a competitive advantage.

A survey was conducted across a broad number of sectors, including the construction industry, and the results showed that an organization's capabilities impact the adoption of big data in the collection and preservation of quality data. Despite the benefits, the construction industry is behind in its adoption of big data. Raguseo (2018) conducted an analysis of the potential downsides and upsides of implementing big data and came to the conclusion that it enhances productivity and organizational capacities in terms of the development of skills and the management of vast data assets. The author suggested undertaking further research to better understand the elements that contribute to and are linked with the challenges of big data adoption. The researchr stated that data privacy and security continue to be the top two threats.

2.4.1 Factors influencing big data adoption

Building Information Modeling, often known as BIM, is a relatively new technology that streamlines the process of integrating and managing information over the entirety of a building's existence. It is possible to increase BIM output by making use of the big data (BD) that is collected throughout the lifespan, which in turn will make BIM more effective. As a result, the rising interest in making use of integrated BD–BIM solutions and the expansion in the availability of integration technologies are pushing the adoption of BD in the construction industry. BIM is utilized in the design and development of green buildings because it makes it possible to address sustainability concerns throughout the process of creating structures. BIM is employed for performance evaluations and simulations, with BD serving as an auxiliary tool. These include simulations of lighting, analyses of CO_2 emissions and energy performance, and various forms of integrated optimization of the performance of buildings. When designers are in the early stages of the design process, the integration of BD and BIM is beneficial because it enables them to obtain an integrated and visible picture of building performance. Integrated solutions for Building Design and Building Information Modeling (BD–BIM) are widely utilized in Facilities Management (FM) for forecasting operating efficiency, supporting efficient design, and eliminating waste. Volk et al. (2014) provided a framework for BD-integrated facility management that was facilitated by BIM. The framework included features such as planning, value realization, leadership, data capture and integration methodologies, and the legal and legislative context. They stated that the framework will provide skills for proactive decision-making and responsiveness.

2.4.2 Management improvement using big data

The implementation of big data is anticipated to facilitate changes in stakeholder interaction, which will, in turn, result in more productive and efficient project management. Hasan and Rasheed (2019) emphasized the significance of the role that BIM plays in integrated project delivery (IPD). The author makes the case that further work has to be done to incorporate BIM into IPD by way of a process of change management. This may be accomplished through the participation of important institutional stakeholders, such as politicians. The optimization of building portfolios and the creation of sustainable and smart cities are both made possible via the collection of real-time information about stakeholders as well as the various phases of construction and operations. The influence of big data on overall construction management and, in particular, project management is a game changer. The author emphasized that the changes in knowledge management and learning that would occur as a result of big data and the technologies that are linked with it will stimulate innovations and efficiency. Business intelligence has the potential to improve performance in the construction industry in at least six different areas. These areas include strategic planning and execution; cost visibility and driver behavior; customer intelligence; forecasting, planning, and predictive analytics; enterprise risk management and process improvement. These components are aligned with quality standards such as six sigma, which aims to reduce or eliminate waste and simplify processes in order to cut cycle times. Ultimately, this will lead to increases in productivity and efficiency. Smith (2016), who highlighted the problems, said that "designers do not providing full access to the models" and technical incompatibilities are preventing efforts to utilize BIM and big data in construction. It is one of the challenges that was highlighted.

2.5 Technology-Organization-Environment Framework

Theory of technical organizational and environmental innovation, a technological innovation process is an ensemble of three interconnected contexts: technological, organizational, and environmental. The term "Technological" refers to the practice of considering technologies inside and outside an organizational ecosystem. This practice encourages businesses to accept and make use of the most recent technologies and to implement change. According to Baker (2012), a company that is contemplating implementing new technologies would first investigate the potential advantages offered by the technology in question, as well as how its implementation can improve operational efficiencies and add value to the company's business. In light of this, a prior study of Jia et al. (2017) has uncovered a multitude of criteria, some of which include, but are not limited to, relative advantage, greater technological competency, perceived benefits/usefulness, and cost efficiencies. Another component of the TOE that evaluates an organization's internal qualities, as well as its strengths and shortcomings, is the organizational context. It encompasses the structure, the procedures, the means of communication, the human and physical capabilities, the involvement, and support of top management, the scale, and the slack resources, among other things. According to Baker (2012), environmental context serves as a lens through which one may examine the possibilities and challenges that are present in a particular business environment as well as the aspects that are associated with an organization's business ecosystem. A number of different components have been uncovered by researchers that either impact the environmental context or are influenced by it. According to Jia et al. (2017), these elements consist of competitive pressures, rules and policies, industrial procedures, marketing possibilities, and value chain dynamics.

Barrett and Koprowski (2002) explored the role of competitive pressure as an environmental variable to moderate technological (complexity, compatibility and expected benefits) and organizational factors (top management support and organizational readiness) to predict the intention to adopt big data analytics in supply chain management.

Atuahene et al. (2020) described that TOE explains an organization’s entire journey of technological innovation: innovation development, adoption, and implementation. The TOE has been one of the old frameworks for advancing technological innovation studies in information systems, and big data barriers can be explored using the TOE.

In big data research, TOE has been used to assess the readiness and capabilities of big data in retail organizations. They presented the obsacles that resist resist the big data adoption in construction industry. They used TOE framework to maping the research scheme binding between big data technology and TOE framework. Table 2.3 shows the conceptual framework of their study.

Table 2.3 Big data barrier investigation with TOE framework.

	Theoritical and literature sources		Framework		Big data process stream
TOE	Big data embedded solution	Big data expertise	*Research themes on barriers*	*Research big data process*	Process streams contextualize

Table 2.3 Big data barrier investigation with TOE framework. (continued)

	Theoritical and literature sources		Framework	Big data process stream	
Technology	Technical	Technology availability	*Technology*	*Organization-external; BDS; Overlap of BDS-BSP; BSP; Overlap of BSP-BDA; and BDA*	Big data sources
	Data	Data management strategy	*Data*		
Organization	People	Individual drive	*People*		Big data storage and processing
		Training	*Knowledge*		
Environment	Organization-wide		*Environment*		Big data application

Source: Atuahene et al. (2023)

2.6 Thematic Analysis

Thematic analysis is a technique used to examine qualitative data. It is typically used for a collection of texts, such an interview or transcripts. The researcher meticulously analyzes the data to pinpoint recurring common themes, which include subjects, concepts, and patterns of meaning. The most popular method for conducting thematic analysis is a six-step process: familiarization, coding, generating themes, reviewing themes, defining and labeling themes, and writing up. Following this procedure can also assist in preventing confirmation bias while developing your analysis. Virginia Braun and Victoria Clarke (Braun & Clarke, 2012) originally established this approach for psychological research. Thematic analysis is a versatile method that may be customized for many types of study.

Step 1 Familiarization: First, familiarize yourself with the data. Prior to examining individual items, it is crucial to have a comprehensive overview of all the acquired data. This may entail transcribing audio, reviewing the text, making first notes, and familiarizing oneself with the data.

Step 2 Coding: We must now proceed to encode the data. Coding involves identifying specific pieces of text, such as phrases or sentences, and creating concise labels or "codes" to represent their content.

Step 3 Generating themes: We will review the codes we have generated, uncover patterns, and begin to develop themes. Themes are typically more expansive in scope compared to codes. Typically, multiple codes are integrated into a unified theme.

Step 4 Reviewing themes: Now we have to make sure that our themes are useful and accurate representations of the data. Here, we return to the data set and compare our themes against it. Are we missing anything? Are these themes really present in the data? What can we change to make our themes work better? If we encounter problems with our themes, we might split them up, combine them, discard them or create new ones: whatever makes them more useful and accurate.

Step 5 Defining and naming themes: Now that you have a final list of themes, it's time to name and define each of them. Defining themes involves formulating exactly what we mean by each theme and figuring out how it helps us understand the data. Naming themes involves coming up with a succinct and easily understandable name for each theme.

Step 6 Writing up: Finally, we'll write up our analysis of the data. Like all academic texts, writing up a thematic analysis requires an introduction to establish our research question, aims and approach. We should also include a methodology section, describing how we collected the data (e.g., through semi-structured interviews or open-ended survey questions) and explaining how we conducted the thematic analysis itself. The results or findings section usually addresses each theme in turn. We describe how often the themes come up and what they mean, including examples from the data as evidence. Finally, our conclusion explains the main takeaways and shows how the analysis has answered our research question. The concept of thematic analysis is shown in Fig. 2.5.

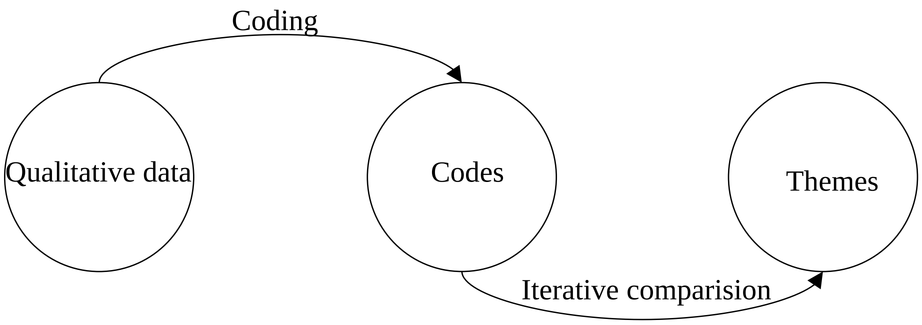

Figure 2.5 Thematic analysis procedure.

CHAPTER 3
RESEARCH METHODOLOGY

This study investigates BD adoption in the Kunming construction industry. The context of the local construction industry may differ from other parts of the global economy. Hence, the local industry context is the primary distinguish of this study from other previous works. This chapter is organized as follows. Section 3.1 describes the research concept; however, it tries to formulate the research mapping that illustrates the relationships among research questions, conceptual framework, research design, data analysis, and research findings. This research design technique is beneficial in perspective of preventing lost research direction. Section 3.2 is the research procedure that defines the order of research operations this study uses.

3.1 Research Mapping

The research procedure draws the linkage between the research questions and the research framework. This link prevents us from losing research direction. It guarantees that the research framework answers the research questions directly. To do so, the research questions are recalled below.

RQ 1: How is the current situation of big data technology adoption in Kunmin’s construction industry?

RQ 2: What are the benefits and drawbacks of big data technology adoption in Kunming’s construction industry?

RQ 3: What factors influence big data technology adoption in Kunming’s construction industry?

The questions are mapped to research framework and binded to research method. In this study, there are three research tools: questionnaire I, questionnaire II, and semi-structured interview questions, as shown in Fig. 3.1.

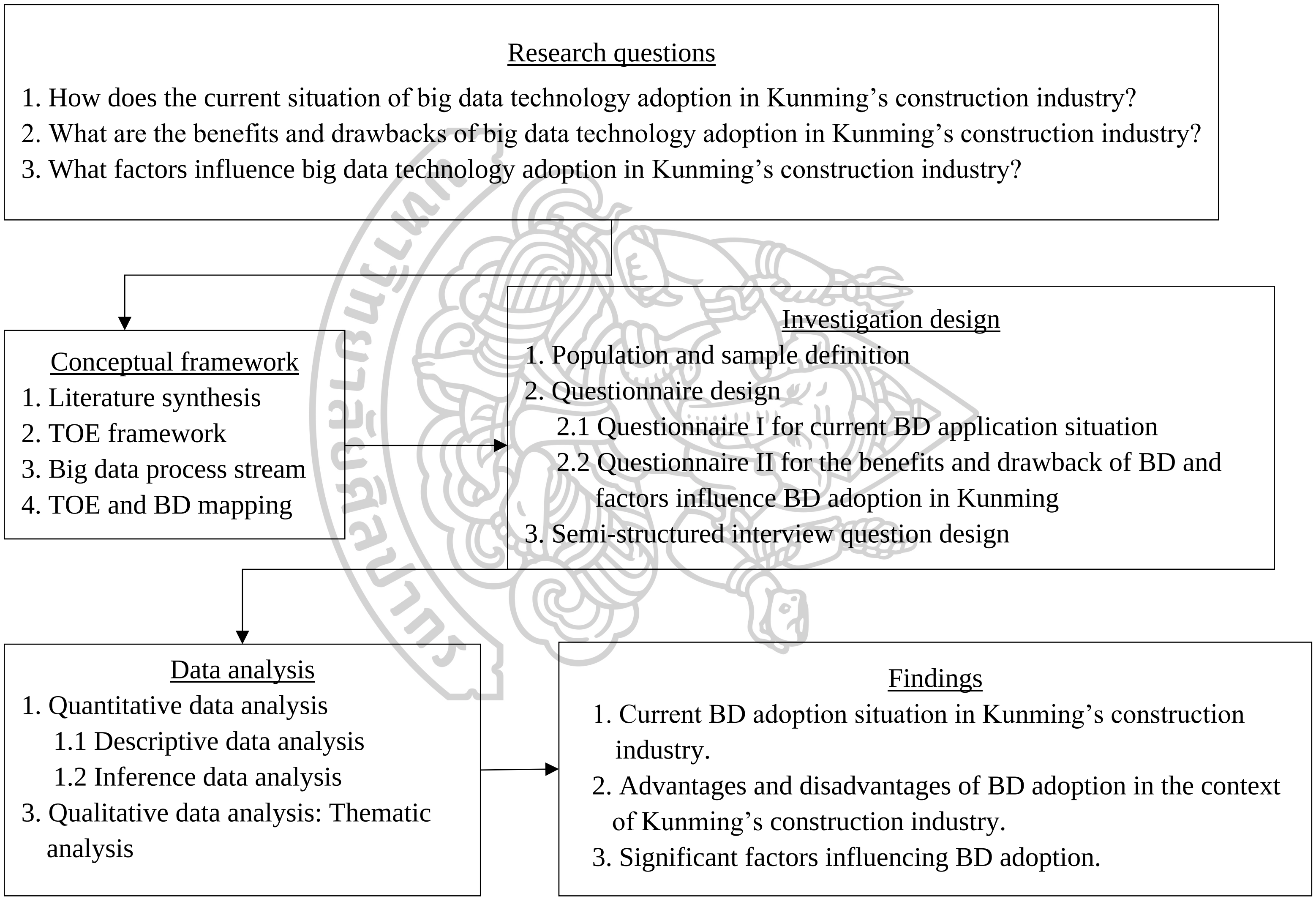

Figure 3.1 Research mapping.

The population of Questionnaire I is the middle and top management levels of construction projects in Kunming. Thus, the researcher sets the sample size to 400 respondents. Nevertheless, Questionnaire II requires expert respondents. Thus, this study confines the participants to be experts in the construction industry of a sample construction company in Kunming and academic professors who research and lecture about construction and big data in Kunming. The number of respondents is ten persons. Finally, the semi-structured interviews will be conducted with five interviewees who have experienced in the Kunming construction industry for at least ten years.

The quantitative data analysis is deployed to analyse Questionnaire I and II to examine the current situation of big data adoption and its impacts in the context of Kunming's construction industry. However, the influence factors are reling on semi-structured interviews; thus, the qualitative data analysis is employed. The reseason is the application of big data is expected in a low level (but need to be confirmed by Questionnaire I). Hence, most of respondents in Questionnaire I cannot answer these questions. Accordingly, the influence factors must be analyzed by experts and use thematic analysis.

Finally, the research mapping shows that the findings can answer the research questions appropriately. They can be matched the the research questions by pairing. All questions are responsed by this study approach.

3.2 Research Procedure

Figure 3.2 shows the steps of this research project.

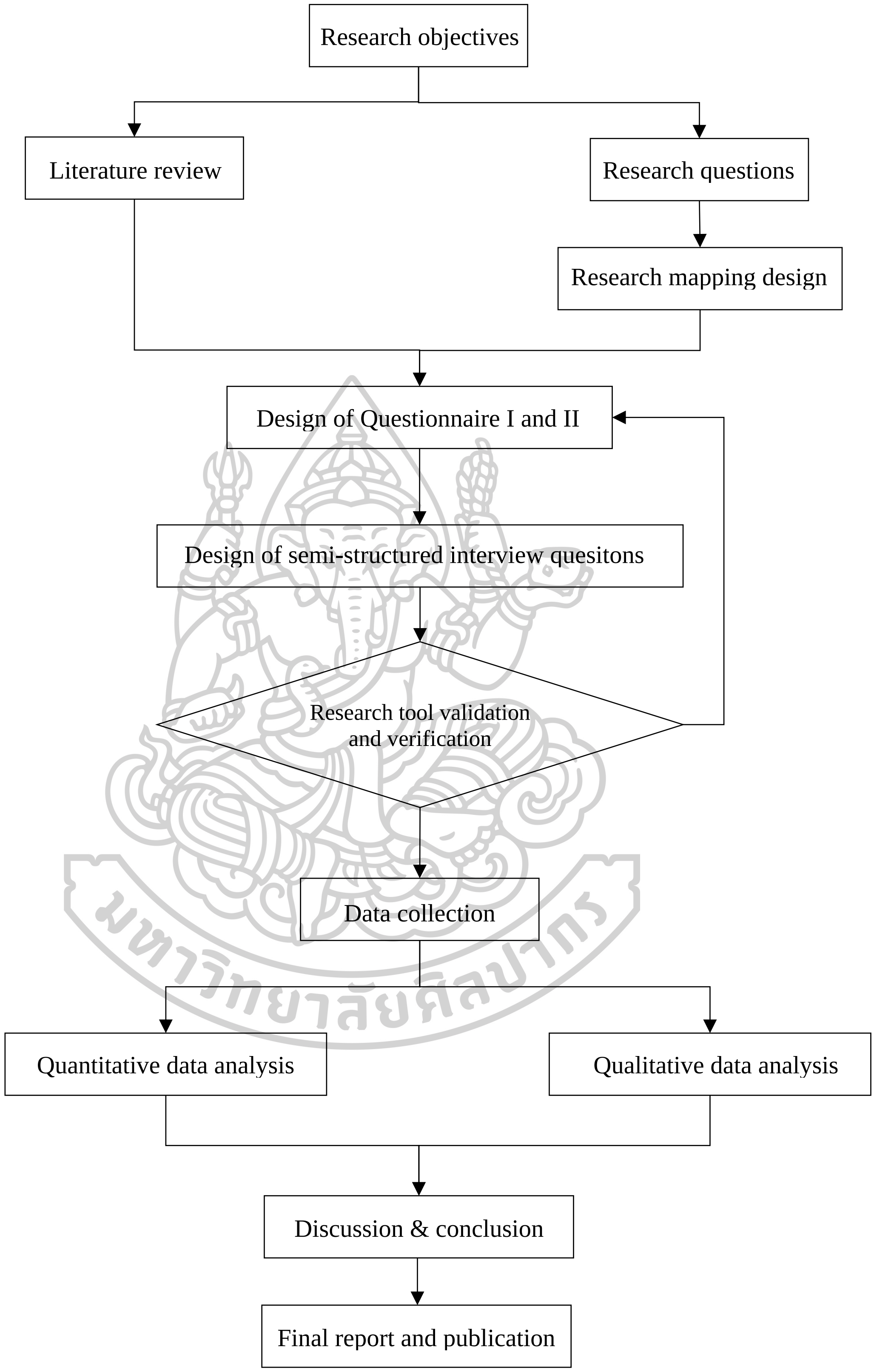

Figure 3.2 Research process flowchart.

CHAPTER 4
RESULT AND ANALYSIS

This research explore knowledge about the situation of using big data technology, identifying benefits and imparments of big data technology adoption, and determining primary factors of big data technology adoption in Kunming's construction industry. There are three questionnaires and data collections in this study. A data collection from construction projects' staff, another one from ten experts in construction industry and adacademic, and the last one from interviewing five expert in Kunming's construction industry. The results of research instrument desing, data collections, and its analysis are comprehensively drawn in this chapter.

4.1 Research Instruments

Three questionnaires were designed based on the literature. By the way, since the technology is emerging in the construction industry, the researcher could not guarantee that these questionnaires are the best. It is appropriate in the situation of this study. Questionnaire I was for staff in the construction industry in Kunming. They were expected to answer the questions with some knowledge of big data technology.

Nevertheless, the researcher expected little about their deep knowledge. Accordingly, the answers were based on their experience with big data technology. The details are shown in Appendix A.

There were three parts to Questionnaire I. The first part is about the representatives' profiles. It also asks about the company profile. The second part starts with asking about big data technology deployment. If the answer is 'No,' the respondent must continue questions 11 to 15. If the answer is 'Yes,' the respondent must jump to questions 16 to 20. The questionnaire was carefully designed because too many questions may lead to blank answers for respondents. Please note that the Item Objective Congruence (IOC) was used to validate the contents of the questionnaire by three experts: one from a Thai university, one from a Chinese college, and one from a construction company in Kunming. The IOC of each item fell between 0.67 and 1.00 (most of them 1.00); thus, the questionnaire is validated.

Questionnaire II was designed for experts in construction industry. The questions require respondents' knowledge and experience to answer even though it is a closed-end question. Part 1 asks about the respondent's information. Part 2 asks about the respondent's opinion. They are divided into three groups. The first group, questions 1 and 2, relates to construction management. The second group, questions 3 to 6, relates to project monitoring and control. The last group, questions 7 and 8, relates to procurement process. Truthfully, this questionnaire did not contain all relevant perspection of big data technology applications; even though, it is a suitable questionnaire for this study. The details of the questionnaire is are shown in Appendex B.

The questionnaire was valiated its contents by using IOC as the questionnaire I. The detail of IOC calculation is trivial. Thus, it is not shown in this report. The same three experts were asked to validate questionnaire. Its items were passed by yielding IOC value between 0.67 and 1.00.

Questionnaire III is the interview questionnaire. Five questions were carefully designed. They are open-end questions. As a result, all five questions may not be expected to propose to the interviewee. It is up to the situation of interviewing. The IOC was used to validate five questions in the questionnaire. They are passed by receiving score 1.00 from three experts of this study. The questions are shown in Appendix C.

4.2 Questionnaire I Result

The respondent number was 327 which accounted to 81.75% return rate. It was satisfied in term of return rate. Table 4.1 shows the profile of the answerers of questionnaire I. Please note that this study collected one respondent per one construction project and of projects were in Kunming.

Table 4.1 Profile of the respondents of questionnaire I.

		Frequency	Percentage
Job position	Engineer	72	22.02
	Supervisor	132	40.37
	Asst. Manager	89	27.22
	Manager	27	8.26
	CEO	7	2.13
Years of experience	0-1	3	0.92
	1-3	43	13.15
	3-5	110	33.64
	5-10	156	47.71
	> 10	15	4.58
Education level	High school	0	0.00
	Vocational	15	4.59
	Higher vocational	27	8.26
	Undergraduate	192	58.72
	Master degree	89	27.22
	Doctoral degree	4	1.22

Unfortunately, the data about the companies such as number of employees, the construction project's size, and type of companies were not allowed to publish. Furthermore, many repondents denied to give the information. Thus, the researcher would like to skip the analysis of these questions. Figure 4.1 to 4.3 illustrate the necessary demographic data of the respondents.

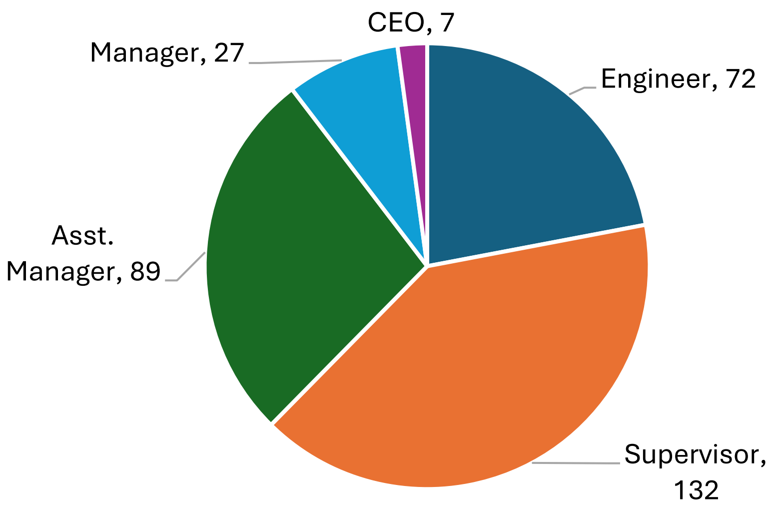

Figure 4.1 Job position of the respondents.

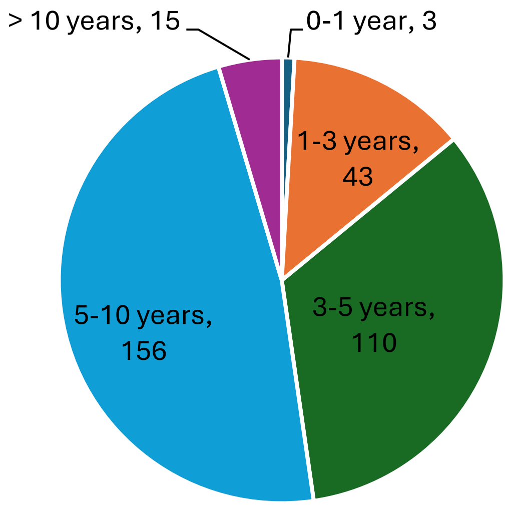

Figure 4.2 Experience of the respondents.

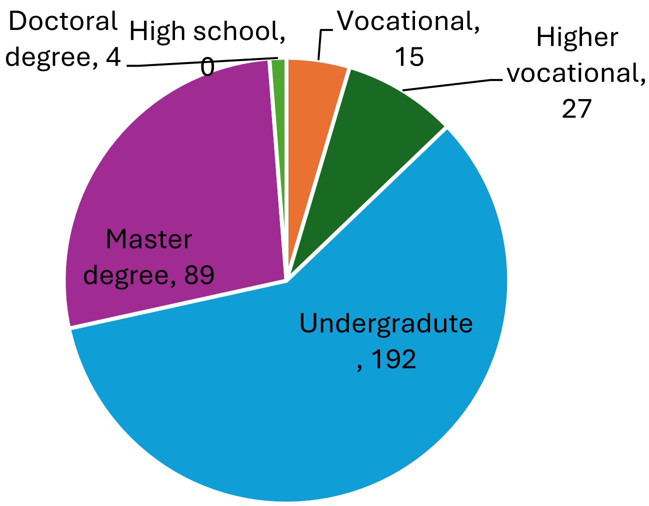

Figure 4.3 Educational level of the respondents.

Table 4.2 shows the current situation of big data technology adoption in construction industry. Question 10 exhibits that most of construction projects do not apply big data technology. It accounts for 91.13%. The reasons were given on question 11. The respondent could select more than one choice. The highest selected answer is 'Noknowledge.' However, the answers 'No budget' and 'No policy' were not different, 65.44% and 67.45%, respectively.

Table 4.2 Current situation of big data technology application.

No.	Question	Response	Frequency	%
Q10	Is your construction project applying big data technology?	Yes	29	8.87
		No	298	91.13
Q11	Why does your company not implement big data?	No budget	195	65.44
		No knowledge	273	91.61
		No policy	201	67.45
Q12	Does your company use BIM?	Yes	283	94.97
		No	15	5.03

Table 4.2 Current situation of big data technology application. (continued)

No.	Question	Response	Frequency	%
Q13	Do you know you can combine BD-BIM in one integration?	I don't know	265	88.93
		I know	33	11.07
Q14	Do you know you can use BD-BIM in facility management for the building lifespan?	I don't know	277	92.95
		I know	21	7.05
Q15	Do you know you can use BD-BIM for simulation and forecast for energy consumption, water usage, and waste management of a building?	I don't know	267	89.60
		I know	31	10.40

Further questions asked for the respondent who do not apply big data technology in her construction project. The big part of projects has implemented building information modeling (BIM) technology, 94.97%. It is obvious that they do not know the big data technology and BIM technology can be seamless combined, see Q13 in Table 4.2. Questions 14 and 15 confirm that the respondents lack of knowledge about the big data technology which can be used together with building information modeling technology.

Table 4.3 shows the opinion of the respondents who did not apply big data technology in their construction project. The number of respondents is 29. They give the score on each question from question number 16 to 20. The mean and standard deviation are shown in the table. However, Table 4.4 interpretes the meaning of the score and also test their coefficient of variations.

Table 4.3 The opinion on big data technology in construction industry.

No.	Question	Score					$\bar{x}$	*SD*
		1	2	3	4	5		
Q16	Big data technology is a good investment in your construction projects.	5	5	7	6	6	3.10	1.40
Q17	Adoption of big data makes company waste the time and workforces.	7	7	9	4	2	2.55	1.21
Q18	Implement of big data technology is not easy and it is for skilled workers only.	1	1	9	12	6	3.72	0.96
Q19	The company is just construct buildings. The product lifecycle analysis in not our job.	1	2	8	7	11	3.86	1.13
Q20	The organizational structure must be changed for implementing big data technology.	0	3	12	8	6	3.59	0.95

Table 4.4 Interpretation of the opinion.

Question	$\bar{x}$	*SD*	$\hat{C}_v$	Interpretation
Q16	3.10	1.40	0.450	Upper middle
Q17	2.55	1.21	0.475	Middle
Q18	3.72	0.96	0.258	High
Q19	3.86	1.13	0.291	High
Q20	3.59	0.95	0.264	Middle

From Table 4.4, their mean and standard deviation are rendered. The coefficient of variation is a common way to quantify the dispersion of a frequency distribution or probability distribution. It is commonly represented as a percentage and is defined as the ratio of the standard deviation to the mean. The formulation of the coefficient of variation is $\hat{C}_v = \frac{\bar{x}}{SD}$. It is a dimensionless measure; usually, $\hat{C}_v < 1$ means the data is low-variance. Table 4.4 shows that the collected data on questions 16 to 20 were low-variance.

The interpretation of this study is defined as follows: $1.0 \leq \bar{x} < 1.7$ is low, $1.7 \leq \bar{x} < 2.4$ is upper low, $2.4 \leq \bar{x} < 3.1$ is middle, $3.1 \leq \bar{x} < 3.7$ is upper middle, $3.7 \leq \bar{x} < 4.4$ is high, and $4.4 \leq \bar{x} \leq 5.0$ is highest. As a result, questions 18 and 19 are in the high level. Question 16 is at the middle level. Questions 17 and 20 are in the middle level. The respondents believe big data technology consumes many human resources and exceptionally skilled staff who can operate, analyze, and utilize the data. Furthermore, big data functions in the construction industry relate to facility and building management. Thus, a construction company thought the building and its lifespan were not associated with her performance. Big data technology looks like a burden to her.

4.3 Questionnaire II Result

The demographic of respondents is shown in Table 4.5. The respondents are experts in the construction industry on both business and academic sides. Seven experts are from the construction industry, and three experts are from colleges and universities. Their experience related to the construction industry is three years and up. One-half of them graduated with a bachelor's degree, and another half graduated with a master's degree.

Table 4.5 Profile of the respondents of questionnaire II.

		Frequency	Percentage
Job categories	Construction industry	7	70
	Academic	3	30
Years of experience	0-1	0	0
	1-3	0	0
	3-5	5	50
	5-10	3	30
	> 10	2	20
Education level	High school	0	0
	Vocational	0	0
	Higher vocational	0	0
	Undergraduate	5	50
	Master degree	5	50
	Doctoral degree	0	0

Recall the characteristics of part 2 in Questionnaire II, which asks for the respondent's opinions. They are divided into three groups. The first group, questions 1 and 2, relates to construction management. The second group, questions 3 to 6, relates to project monitoring and control. The last group, questions 7 and 8, relates to the procurement process. Table 4.6 shows the result of the second part of Questionnaire II.

Table 4.6 Application of big data technology in construction industry.

No.	Question	Score					$\bar{x}$	*SD*
		1	2	3	4	5		
1	BD can be used for reducing conflict amongst project stakeholders.	2	4	3	1	0	2.30	0.95
2	BD can be used for reducing time spent on construction site inspection.	2	3	3	1	1	2.60	1.26
3	BD enables real time information updating between sites and head office.	0	2	2	5	1	3.50	0.97
4	BD contributes to quick response on construction site's issues.	0	0	3	5	2	3.90	0.74
5	BD contributes to identify construction defect and its causes.	0	6	3	1	0	2.50	0.71
6	BD contributes to achieving time, cost, quality, and safety.	1	4	2	2	1	2.80	1.23
7	BD helps to select and award of contractors and sub-contractors.	0	2	3	3	2	3.50	1.08
8	BD helps to submitting competitive bid for projects	0	3	3	2	2	3.30	1.16

Table 4.7 illustrates the interpretation of the result. Then, Table 4.8 draws the results of eight questions.

Table 4.7 Weighted average for five-point likert scale.

Weighted average	Result	Result Interpretation
1.00 – 1.79	Strongly disagree	Very uninfluential
1.80 – 2.59	Disagree	Uninfluential
2.60 – 3.39	Neutral	Do not know
3.40 – 4.19	Agree	Influential
4.20 – 5.00	Strongly agree	Very influential

Table 4.8 Eight questions interpretation.

No.	Mean	S.D.	$\hat{C}_v$	Interpretation
1	2.30	0.95	0.412	Uninfluential
2	2.60	1.26	0.487	Do not know
3	3.50	0.97	0.278	Influential
4	3.90	0.74	0.189	Influential
5	2.50	0.71	0.283	Uninfluential
6	2.80	1.23	0.439	Do not know
7	3.50	1.08	0.309	Influential
8	3.30	1.16	0.351	Do not know

Three factors are defined above. Then, the mean and standard deviation based on the factors are calculated. Table 4.9 shows the interpretation of three factors.

Table 4.9 Three factors result.

Group	Description	$\bar{x}$	S.D.	$\hat{C}_v$	Interpretation
1	Construction management	2.45	1.10	0.449	Uninfluential
2	Project monitoring and control	3.18	0.99	0.311	Do not know
3	Procurement process	3.40	1.10	0.322	Influential

From Table 4.8, the influential factor is the procurement process. That means big data's functions are useful for applying in the procurement process. It can collect data about suppliers' performance, such as cost, delivery performance, product and service quality, and safety of sub-contract operations. Project monitoring and control factors are in question. It is not influential; however, inevitably, this factor is still important. The real-time data collection feature helps project monitoring and control be simple. However, construction project management can use this information to solve problems and predict some issues.

Nevertheless, to confirm that these factors are significantly different, the analysis of variance is used to analyze the data based on the score of each group.

H_0: Three factors are not significant difference.

H_1: Three factors are significant difference.

Figure 4.4 is an ANOVA table for three groups. Type I error (α) is 0.05. Accordingly, since p value = 0.015 < α, the null hypothesis is rejected. Thus, three factors are significant difference. Note that Fig. 4.5 illsutrates the four-in-one graph of the data.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Group	2	10.27	5.137	4.42	0.015
Error	77	89.52	1.163		
Total	79	99.80			

Figure 4.4 Analysis of variance.

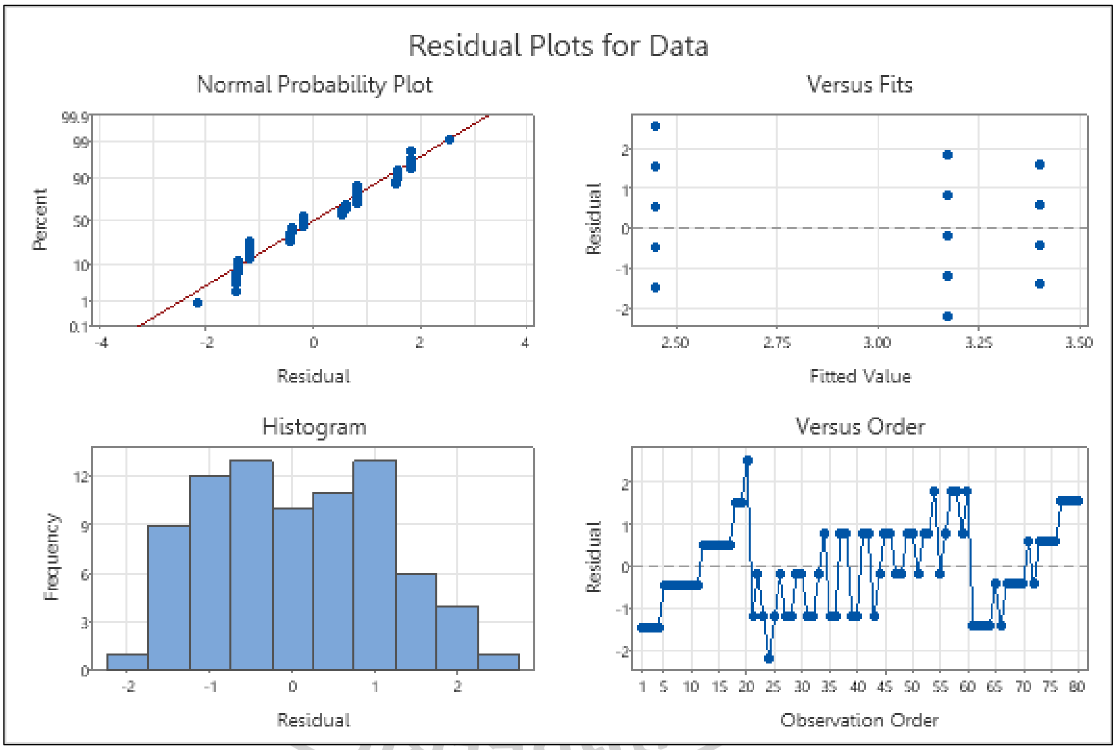

Figure 4.5 Residual plots for the data.

4.4 Questionnaire III Result

Five interviews were conducted via an online meeting platform and face-to-face method. The interviewees are working on construction projects that use big data technology for at least one function of their operations. Furthermore, the interviewees have worked in the construction industry for at least ten years.

The six steps of thematic analysis were conducted. Nevertheless, it is trivial to draw every single step in this report. Thus, the thematic analysis table is shown to analyze five interview questions, see Table 4.10.

Table 4.10 Thememic analysis.

Question	Code	Theme	Naming
1	• Building information modeling • Data base • Data analytic • Augmented system • Extension of existing system • Skilled data analysis staff	• Building information modeling • Extension	• BIM technology
2	• Real-time data • Cost analysis and control • Delivery time analysis • Quality and safety reports • Competitive bid • Reduce paperwork	• Real-time data • Analysis	• Real-time data and analysis
3	• May be or may be not • Efficient data analysis • Building information modeling • Artificial intelligence	• Building information modeling • Artificial intelligence	• BIM technology and plug-in/embedded AI
4	• May be or may be not • Data analysis cost • Big data application management • Internet of things • Cost, time, quality, and safety	• Internet of things • Cost, time, quality, and safety	• Internet of things • Cost, time, quality, and safety

Table 4.10 Themetic analysis. (continued)

Question	Code	Theme	Naming
5	• May be or may be not • Expecting that • More analysis and control • Waste control • Big investment • Law and regulations	• Not sure • Waste management and control	• Possible with more investment on waste management and control

From Table 4.9, the interviews are squeezed into codes that are common and frequently mentioned. Then, the themes of each perspective that are bold in each question are identified. Please note that the theme may be the same, even with different questions. Finally, the themes are simplified to ordinary words and efficiently communicated.

4.5 Discussion

Recall that the study was conducted in the context of Kunming's construction industry. The results are not guaranteed to be the same in other contexts. Notwithstanding, the techniques and methods used in this study are helpful. The research questions are discussed based on the collected data and analysis.

4.5.1 The current situation of adopting big data technology

There were 327 respondents in this part of the research questions. It is found that only 8.87% are adopting big data technology in their construction project. The main reason for not implementing this technology is a need for more knowledge. However, the other two reasons, lack of investment and no policy, are also significant. Interestingly, 94.5% of construction projects implement building information technology. Nonetheless, 92.95% of the respondents must learn that big data technology can extend BIM technology. The exciting part is that they have yet to learn that augmented BD-BIM can be used to monitor the building through its life cycle. Furthermore, the respondents have yet to learn that facility management functions such as energy consumption, water usage, and waste management are efficiently achieved by using augmented BD-BIM.

Twenty-nine out of three-hundred twenty-seven construction projects are implementing big data technology. The opinions of the respondents provide some interesting information. Even if they apply big data technology in their construction projects, they complain about the high requirement of skilled staff who can deal with big data analysis. Furthermore, a construction company is not related to a building management company. Thus, the benefits of big data technology on facility management are not in a construction company's concern.

4.5.2 Benefits and drawbacks of adopting big data technology

The respondents in this section were experts in the construction industry, both in business and academic organizations. Seven out of ten respondents are from business organizations, which is a flavor of this study because the researcher needs to investigate more in practitioners.

It was found that the benefits of big data technology that impact technology adoption are the 'procurement process.' It facilitates many functions in procurement operations. Since a construction project uses many contractors, sub-contractors, sub-sub-contractors, vendors, and suppliers, big data technology yields much information for monitoring, controlling, and awarding to stakeholders. The interesting understanding is that this feature is also embedded in BIM technology. It is merely combined with big data technology. Real-time data acquisition is the most influential benefit of big data technology. It helps management to make a decision accurately and timely. Nevertheless, using big data analysis in prediction and problem-solving features is in doubt. Achieving that goal requires more hardware, software, and human resources investment.

4.5.3 The primary factors of adopting big data technology

Five experienced respondents were interviewed. The primary regulation for selecting an interviewee is that her company is implementing big data technology for at least one function of its operations. Thematic analysis was used to analyze the qualitative data. The performance of this technique barely relates directly to the researcher’s ability.

The theme and naming tell us that building information technology is the primary technology appropriated to be augmented by big data technology. It is possible to implement big data technology solely; however, there are better strategies. Many big data technology packages are invented to be plugged into BIM technology. It is plausible to extend its features.

Facility management features require more investment in internet-of-thing technology for acquiring real-time data efficiently. The data can be analyzed to improve the cost, time, quality, and safety of construction projects and facility/building management. Ultimately, it promotes sustainable construction practices. The acquired data about energy consumption, water usage, and waste management benefit this circumstance.

CHAPTER 5
CONCLUSION

The findings of this study are worthwhile. It is not only beneficial for the industry but also for the academic section. The acknowledgment of the opinion of the industry section guides the academic section to do more research in the correct direction. This chapter draws the search findins in form of conclusion for answering the research questions and objectives.

5.1 Research Findings and Conclusion

The current situation of big data technology adoption in Kunming’s construction industry is not proliferating. There are barriers such as lack of knowledge, skilled staff, and investment. Building information modeling technology can be extended by big data technology. However, it needs to be promoted in the construction industry. The academic section can support the industry by training staff with courses on big data applications. Additionally, there is a gap in obligation in the construction industry. Usually, a construction company is not a building management company. Thus, the usefulness of big data technology is interrupted when the responsibility is changed.

The principal benefit of implementing big data technology is the productive improvement of procurement operations. Due to the complicity of construction projects, it colligates with many parties in the industrial value chain, such as contractors, sub-contractors, sub-sub-contractors, material suppliers, and other outsources. Big data technology helps collect and analyze parties' data for monitoring, expediting, controlling, and awarding the parties. Besides, internet-of-thing technology is needed in the system for acquiring real-time data, which influences the most benefits of big data technology adoption. Nonetheless, to do so, it needs a significant investment.

The primary factor influencing big data technology adoption is building information modeling (BIM) technology. It allows big data technology to be initiated straightforwardly and seamlessly. The augmented BD-BIM is an excellent strategy to carry out big data technology. The most potent and ultimate goal is internet-of-thing technology, which can cover all operations and functions of construction processes. Furthermore, it is required to sustainable construction practices can be achieved by using big data technology in facility and waste management functions.

5.2 Future Research Direction

The exciting research direction is finding specific big data technology suitable for each construction phase and the gap between construction companies and building management companies. Furthermore, a framework of big data technology adoption in the context of building information modeling technology is needed for efficient technology adoption.

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APPENDIX

APPENDIX A

QUESTIONNAIRE I

Questionnaire I

This form is the questionnaire for a research project of Mr. Desong Yang, a student in the Master Degree of Engineering Program in Engineering Management at Silpakorn University. The topic is "**Big Data Adoption in Kunming Construction Industry, the People's Republic of China: An Empirical Study.**"

There are two parts. The first part asks about the respondent's background in the construction industry. The second part asks the opinion about the adoption and impacts of the Big Data application in the Construction industry. The answers are a five-point Likert scale that you can choose based on your idea.

Score 1 means 'strongly disagree',

Score 2 means 'disagree',

Score 3 means 'neutral',

Score 4 means 'agree', and

A score of 5 means 'strongly agree'.

However, you may skip this part if you have no experience with Big Data in construction projects.

Thank you very much for your cooperation. The data are kept secret and unopened to a third-party organization. The purpose of this study is academic only.

Part I: Profile

No.	Question	Answer
Q1	Do your construction project in Kunming?	□ Yes □ No
Q2	How big is your construction project?	………………..Yuan (estimate)
Q3	How many employees are on your construction site?	……………….employees
Q4	Is your construction project state-owned?	□ Yes □ No
Q5	What is your position in the construction project?	□ Engineer □ Supervisor □ Asst. Manager □ Manager □ CEO □ Other……………
Q6	How long have you been working in the construction industry?	□ 0-1 year □ 1-3 years □ 3-5 years □ 5-10 years □ More than ten years
Q7	What is your education level?	□ High school □ Vocational □ Higher vocational □ Undergraduate □ Master degree □ Doctoral Degree
Q8	What is your education major?	………………….
Q9	How old are you?	…………………. years

Part II: Current situation of big data technology application.

No.	Question	Answer
Q10	Is your construction project applying big data technology?	☐ Yes ☐ No
If 'Yes', go to Question Q17. If 'No', go to Question Q11.		
Q11	Why does your company not implement big data?	☐ No budget ☐ No knowledge ☐ No policy ☐ Other………
Q12	Does your company use BIM?	☐ Yes ☐ No
Q13	Do you know you can combine BD-BIM in one integration?	☐ I don't know ☐ I know
Q14	Do you know you can use BD-BIM in facility management for the building lifespan?	☐ I don't know ☐ I know
Q15	Do you know you can use BD-BIM for simulation and forecast for energy consumption, water usage, and waste management of a building?	☐ I don't know ☐ I know
You are done for the survey. Thank you for your cooperation.		

Part III: Opinion.

No.	Statement	Score				
		1: strongly disagree	2: disagree	3: neutral	4: agree	5: strongly agree
Q16	Big data technology is a good investment in your construction projects.					
Q17	Adoption of big data makes company waste the time and workforces.					
Q18	Implement of big data technology is not easy and it is for skilled workers only.					
Q19	The company is just construct buildings. The product lifecycle analysis in not our job. So, big data is not necessary.					
Q20	The organizational structure must be changed for implementing big data technology.					

APPENDIX B

QUESTIONNAIRE II

Questionnaire II

This form is the questionnaire for a research project of Mr. Desong Yang, a student in the Master Degree of Engineering Program in Engineering Management at Silpakorn University. The topic is "**Big Data Adoption in Kunming Construction Industry, the People’s Republic of China: An Empirical Study.**"

There are two parts. The first part asks about the respondent's background in the construction industry. The second part asks the opinion about the adoption and impacts of the Big Data application in the Construction industry. The answers are a five-point Likert scale that you can choose based on your idea.

Score 1 means 'strongly disagree',

Score 2 means 'disagree',

Score 3 means 'neutral',

Score 4 means 'agree', and

A score of 5 means 'strongly agree'.

Thank you very much for your cooperation. The data are kept secret and unopened to a third-party organization. The purpose of this study is academic only.

Part I: Respondent's information

No.	Question	Answer
Q1	What is your job category?	□ Construction industry □ Academic
Q2	What is your education level?	□ High school □ Vocational □ Higher vocational □ Undergraduate □ Master degree □ Doctoral Degree
Q3	How long have you been working in your job position?	□ 0-1 year □ 1-3 years □ 3-5 years □ 5-10 years □ More than ten years

Part II: Respondent's opinion about big data in construction industry.

No.	Statement	Score				
		1: strongly disagree	2: disagree	3: neutral	4: agree	5: strongly agree
1	BD can be used for reducing conflict amongst project stakeholders.					
2	BD can be used for reducing time spent on construction site inspection.					
3	BD enables real time information updating between sites and head office.					
4	BD contributes to quick response on construction site's issues.					
5	BD contributes to identify construction defect and its causes.					
6	BD contributes to achieving time, cost, quality, and safety.					
7	BD helps to select and award of contractors and sub-contractors.					
8	BD helps to submitting competitive bid for projects					

APPENDIX C

QUESTIONNAIRE III

Questionnaire III (Interview)

This form is the questionnaire for a research project of Mr. Desong Yang, a student in the Master Degree of Engineering Program in Engineering Management at Silpakorn University. The topic is "**Big Data Adoption in Kunming Construction Industry, the People's Republic of China: An Empirical Study.**"

<u>Interview Question 1:</u>

How do we apply big data technology to a construction project?

<u>Interview Question 2:</u>

What are the relative advantages of implementing big data technology?

<u>Interview Question 3:</u>

Can big data combine with other construction technologies to improve the competitiveness of construction projects?

<u>Interview Question 4:</u>

Can big data have used for improving construction management?

<u>Interview Question 5:</u>

Can big data technology promote sustainable construction?

VITA

NAME Yang Desong