MODELING 5D BUILDING INFORMATION MODELING DRIVERS FOR EFFICIENT CONSTRUCTION PROJECT DELIVERY

BY

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL

FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE IN MASTERS OF SCIENCE (M.Sc.) IN PROJECT MANAGEMENT TECHNOLOGY

APRIL, 2024

CERTIFICATION

This is to certify that this work **"Modeling 5D Building Information Modeling Drivers for Efficient Construction Project Delivery"** was carried out by **Muhammad, Abdulqadir Kabir** with registration number **20204253858** in partial fulfillment for the award of the degree of M.Sc in Project Management in the department of Project Management Technology of the Federal university of Technology Owerri.

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DEDICATION

I dedicate this work to Almighty Allah for making it possible.

ACKNOWLEDGEMENTS

All thanks are to God Almighty for making it possible. I wish to acknowledge the effort of my supervisor in person of Dr. Ben Amade, for making sure that this thesis is done perfectly and accurately, I also wish to acknowledge my HOD’s effort in person of Dr. I.I Echeme for ensuring easy and fast completion of this program and the Dean of SLIT Prof. K. U. Nnadi, and other lecturers in the department viz, Dr. G.C. Enyinna, Prof. E.C.Ubani, Prof. K. A. Okorocha, and the entire staff of Department of Project Management Technology.

I also wish to sincerely acknowledge my parents support and prayers in persons of Mal. Muhammad Kabir and Malama Halimah Muhammad Abdullahi. My brother Muhammad Umar Faruq for his advices and financial supports. My sisters Khadijah Muhammad Abdullahi and Aisha Muhammad Abdullahi together with their entire families, my younger brother Shamasudden Muhammad and his sister Fatimah Muhammad Kabir and lastly Adam Abdulrazak my nephew.

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ABSTRACT

This study models 5D BIM drivers for efficient construction project delivery in Nasarawa State. This study was motivated by the need to deploy 5D BIM in construction projects for efficient project delivery. This study specifically evaluated the extent of deployment of 5D BIM on construction project, identified the drivers of 5D BIM on construction project delivery. The study is guarded by the technology acceptance model (TAM), lean theory and social network theory. This study adopted a survey mix of quantitative and qualitative research methods, while the census sampling technique was used in selecting a total of 71 population as the sample size, and 5 construction companies currently undertaking projects in Nasarawa state were consulted. The instrument for data collection and measurement consist of well structured questionnaire modeled in likert scale in addition to semi structured interview as well as personal observations used in eliciting information from the construction firms. The questionnaires were validated for reliability using the Crombach's alpha test. The data collected were presented using descriptive statistical tools in the form of frequency, figure and charts, while the factor analysis and DEMATEL(decision making, trail and evaluation laboratory) analysis was used. The findings from the study indicated that there is a low level of deployment of 5D BIM and non utilization of the identified drivers for efficient construction project delivery. The factor analysis reduced the twenty two drivers into eight namely: procurement and supply management, real time monitoring, visualization enhancement, adoption of technology and innovation, change management, shorter project life cycle, early involvement of contractors and improved cost estimation. The eight drivers were subjected to cause and effect test where five drivers with low influence fell within the effect group and three drivers with higher influence fell within the cause group. This study's recommendations include; to create awareness for professionals in construction company on 5D BIM, acceptance of digital modernization by construction companies, provisions of lecture and seminars by companies to educate professionals on the usage of 5D BIM on construction, provision of simple software applications and platforms for 5D BIM and inclusion of 5D BIM study in educational curriculum to allow for students to be conversant with 5D BIM in construction.

Keywords: 5D BIM, Drivers, Modeling, Construction Projects, Construction Industries, Effective Project Delivery, Nasarawa State.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Saraireh and Haron (2020) stated that, BIM started in the 1950s and 1960s with the application of computer-aided design (CAD), after that CAD software was developed in 1963 by Ivan Sutherland by creating a graphical interface named Sketchpad, in 1970s the French Aerospace Company developed two dimensions (2D) and then the three dimensions (3D). Subsequent, in the 1980s to 1990s, Autodesk become a popular developer and leading in the information technology (IT) industry with their product AutoCAD. The transformation from 3D model to the 4D model was introduced to help stakeholders, especially in the architectural, engineering and construction industry in managing schedules and resources with respect to time. Later, 5D was developed to relate directly to digital cost estimating. This 5D model is valuable to cost estimators or quantity surveyors in checking the estimated cost of projects. The development of 6D is related to sustainability and 7D more to facilities management. However, the development of nD is dependent on the functions. As mentioned by (Beveridge, 2012), 8D was identified as integrated project delivery and maintainability, 9D for acoustics, 10D for security, and 11D was for heat. This shows that the transition of BIM started in the 1950s and continues to the present day. They further discussed on problems relating to 5D BIM which includes lack of understanding and knowledge. This is due to the complex nature of 5D BIM which requires users to possess a deep understanding and knowledge of the technology, which is a serious challenge for some individuals and organizations. Other problems as relating to cost and time where 5D BIM requires substantial investments in terms of software, hardware and training. Another problem which relates to resistance to change is where stakeholders such as project managers, contractors and suppliers can also hinder the successful implementation of 5D BIM. The advantages of 5D BIM as they further stated includes cost saving due to improved cost control, accurate estimations and reduced rework. Another advantage which includes time saving which has to do with integration of cost and time information in BIM model allows for better scheduling and sequencing.

Agostinelli, Cinquepalmi and Ruperto (2019) opined that, 5D BIM simulation models allows the inclusion of 3D model and now the fifth model dimension in order to view the progress of activities and the related costs of projects overtime, it is a 3D BIM model that represents the geometry and when attached with time it will become 4D BIM and then 5D when cost is attached. The use of 5D model provides methods for extracting and analyzing costs, so also evaluating alternative scenarios resulting to more accurate and predictable estimates, quantities, materials equipment and labor. They further stated that the numerous benefits of 5D BIM includes improved cost estimation, time savings, better decision making, enhanced collaboration and so on. Arayici et al. (2011) stated that limited industry expertise and skill gaps are a major problem relating to 5D BIM in construction. Successful implementation of 5D BIM requires specialized skills and knowledge, however lack of industry expertise in effectively utilizing 5D BIM, results in potential skill gap and challenges in its adoption. Eadie et al. (2017) also stated that lack of standardized processes and protocols which can lead to inconsistency in data management and interoperability issues are also major problems of 5D BIM in construction.

Lipman (2020) stated that 5D BIM drivers refer to the factors or elements that influence the implementation and adoption of 5D building information modeling (BIM) in construction projects. These drivers are crucial in leveraging the benefits of 5D BIM and ensuring its successful implementation. These drivers includes and are not limited to the following; cost control, time management, clash detection and coordination, quantity takeoff and estimation, visualization and communication and so on.

1.2 Problem Statement

To identify the major problems relating to this study, some major benefits of other related studies need to be identified and the problems contained in them and the consequences when people choose to ignore them and how their identification will benefit the public in line with the adoption of 5D BIM drivers for efficient construction project delivery. Eastman et al. (2011) stated that one of the major benefits of 5D BIM drivers in the delivery of construction projects efficiently includes cost control and estimation accuracy. The adoption of 5D BIM drivers in construction allows for more accurate estimation of project costs by integration cost data with the 3D model. This adequately helps in better cost control and reducing the chances of budget overruns. They further added that improved time management is achieved when project schedules can be efficiently managed by integrating the time dimension into the model. This then will lead to better coordination, reduced delays and faster project delivery. Shash et al. (2015) also stated that another benefit of 5D BIM drivers in construction project delivery is that 5D BIM promotes collaboration amongst project stakeholders by providing a single shared platform for communication and information exchange among professionals. This improves coordination, reduces conflict among professionals and facilitates better decision making.

With respect to 5D BIM deployment for efficient construction project delivery, the major problems faced by construction industries are seen as stated by different authors which include Salim et al. (2017), where he stated that complexity of data integration where integrating different types of data such as cost schedule and 3D models in 5D BIM can be complex, especially while dealing with diverse and large datasets. This can eventually result in data inaccuracies and difficulties in model synchronization. Olsson et al. (2017) also stated that resistance to change is another problem faced in the deployment of 5D BIM in construction projects. The implementation of 5D BIM requires a change in traditional working practices and may face resistance from various stakeholders, including contractors and subcontractors. Overcoming resistance to change can be significant in adoption of 5D BIM in construction project delivery.

The above problems are directly related to this study more so, the awareness and implementation of 5D BIM models in Nigerian construction projects is rather low and slow especially amongst contracting firms. To this end it is highly important to learn and adopt the 5D BIM models in order to mitigate delays in project execution and cost overrun. When the above benefits and problems associated to 5D BIM are ignored our construction project in Nigeria will constantly be faced with the above stated problems and modernization in construction projects will hardly be achieved.

Nigerian construction industry is facing so many challenges, majority of which are problems of lack of communication system and adequate building information which is the BIM (Nazifi 2020)

Another problem is cost, since 5D BIM model specifically has to do with cost utilization in construction projects, the cost of implementing it is another problem that most projects contactors usually shy away from and therefore the use of 5D BIM model is usually minimal and, in some cases, totally not in use. The non-usage of BIM models ranging from the 3D to 5D are neglected by some construction project industries and these neglects calls for serious concern to all and sundry as neglecting of these models will hinder project delivery and accurate execution of the project.

From my Pre-field survey and interactions with professionals in various construction companies, it has been observed that the awareness and implementation of 5D BIM models in construction projects delivery is rather low and slow especially amongst contracting firms. To this end, it's highly important to learn and adopt the BIM models in order to mitigate delays in project execution and cost overrun.

1.3 Objectives of the study

The aim of this research is to model the 5D BIM drivers for efficient construction project delivery.

The study seeks to achieve the following objectives namely;

i) To evaluate the extent of deployment of 5D BIM on construction project delivery in Nasarawa state

ii) To identify the drivers of 5D BIM on construction project delivery in Nasarawa state

iii) To model the 5D BIM drivers on construction project delivery in Nasarawa state using DEMATEL analysis so as to isolate the drivers with the highest influence on construction project delivery.

iv) To present the isolated 5D BIM drivers in a simple model for easy use in efficient construction project delivery

1.4 Research Questions

The following research questions are postulated:

i) To what extent is 5D BIM drivers are deployed in construction project delivery?

ii) What are the 5D BIM drivers used in construction projects delivery in Nasarawa state?

iii) How is the DEMATEL analysis used in modeling the 5D BIM drivers on construction project delivery in Nasarawa State?

iv) How are the isolated drivers presented for easy use in efficient construction project delivery?

1.5 Justification of Study

To justify this study as it relates to the government is that it will help the government in terms of financial revenues or tax received as a percentage of totally construction cost. 5D BIM models are mostly associated with big projects that cost tens and hundreds of millions or a few billions. The percentage received by government as tax will relatively be higher than those smaller projects that do not make use of BIM models.

It's also has significance in learning as it allows students and researchers to gather ample information with regards to the study.

In relation to the community, it is can help minimize the risk of constructing a substandard large project that might cause havoc to the community. This study will help persuade contractors to make use of 5D BIM model in executing projects safely and within a given time frame.

The importance of this study will not only be limited to the above points but rather will extend to the point of efficient construction project delivery by the construction industries.

1.6 Scope of Study

1.6.1 Content Scope:

The study focus on modeling 5D BIM drivers for efficient construction project delivery, with the objectives of evaluating the extent of deployment of 5D BIM on construction project delivery at the same time identifying the drivers of 5D BIM on project delivery in Nasarawa state.

1.6.2 Time Scope:

The study is carried out as it is a compulsory request for the award of Masters of Science (Msc). The duration of the study will be for the period of six months to enable the researcher meet the targeted date for submission and approval of the research work.

1.6.3 Geographical Scope:

This study shall be limited to the construction industries in Nasarawa state. For the purpose of this study, Nasarawa state major cities comprising of Lafia, Keffi and Karu LGAs of the state will be consulted because they are the places major construction projects are taking place.

The target respondents for the study will be the principal actors in the construction industry, namely, the architects, structural engineers, quantity surveyors, builders and project managers.

CHAPTER TWO

LITERATURE REVIEW

2.1 Conceptual Review

2.1.1 Building Information Modeling (BIM)

Arayici, Egbu and Coates (2012) opined that, there are few available definitions for BIM, they then proposed a more comprehensive and operational definition for BIM which will give the reader a clear understanding behind the real agenda of BIM. They gave particular consideration to things like the natural environment, user environment and owner satisfaction throughout the life cycle of the building. They defined BIM as the utilization of database infrastructure to encapsulate built facilities with specific view-points of stakeholders. They added that it's a methodology to integrate digital description of all the building objects and their relationship to others in a precise manner, so that stakeholders can query, simulate and estimate activities and their effects on the building process as a life cycle entity. This means that BIM can help in the provision of required value judgments for creating a more suitable infrastructure which will eventually satisfy their occupants and owners. Building information modeling (BIM) as an emerging tool for collaboration within the Architectural Engineering and construction industry, has been adjudged as one of the models for containing information within the nooks and crannies as well as the life cycle of a building construction project (Amade et al. 2018). Belgian Guide for the Construction Industry (2015) argued that Building Information Modeling (BIM) has many interpretations, definitions and meaning, but this is due to the fact that the application of BIM have evolved over time and its potential is wider than it was potentially seen. BGCI then stated that BIM is a process whereby different actors work together and efficiently exchange information (data and geometry) and collaborate them to provide a more efficient construction process like less errors and faster construction, but also more efficient buildings that produce less waste and are cheaper but also easier to operate, this definition is contained and extracted by BGCI from BIM handbook.

BIM means different things to different professionals, some professionals view BIM as a software application while others view it as a process for designing and documenting information on buildings, others sees it as a holistic approach to design, construction and maintenance of building. But the common and consensus definition of BIM is, the process of combining information technology to create digital representation of a project. It also integrates data from many sources and evolves in parallel with the real project across its entire timeline including design, construction and in-use operational information (Kjartansdottir et al., 2017). Borrmann, Konig, Koch and Beetz (2018) argued that BIM is a comprehensive digital representation of a built facility with great information depth. He further noted that it includes the three dimensional geometry of the building components at a defined level of details. Mohammad, Abdullah and Ismail (2018) also stated that BIM is not software as many people in the construction industry will think. It is the use of different dimensions data in the process of producing and managing building data during its lifecycle with adequate and appropriate building information software to improve the productivity of building design and constructions.

Doan et al. (2019) stated that there is no common or unique BIM definition for construction industries in countries like New Zealand, because BIM handbook stated that there are many definitions of BIM and the focus will vary, meaning the constituted company only chooses the definition and applies it according to the use in that particular context or period. The Institution of Structural Engineers BIM panel (2021) argued that BIM as seen by PAS 119-2-2013 is building information modeling and is a process of designing, constructing or operating a building or infrastructural asset by the application and use of electronic object-oriented information.

2.1.2 5D BIM

Assaf, Salami, Salhab and Hammad (2023) stated that 5D BIM is a model that is generated by integrating cost data into the developed 4D BIM model on the Novisworks tools. The developed BIM model is considered to have a level of details as it covers criteria like price information on quantities and cost and schedule data. Moses, Heesom and Oloke (2020) opined that 5D BIM process is a digital construction information flow that allows constructors, employees and the project to generate accurate cost and essential estimating information with model element attributes like size, area, object, family type and productivity projectors. Smith (2014) argued that 5D means living cost plan and a modern technique which is used within traditional frameworks and behavior of how technology is used is more important than the software.

Zaman and Nast (2022) also opined that 5D BIM is a building information modeling which adds generally a 3D model with 4D BIM scheduling and 5D BIM cost estimation. It is a progressive and developed technology in the architectural engineering and construction industry (AEC industry) that can be applied in managing and extracting quantities and cost. It also allows users to handle the logistical site plan. But Lee, Cheah Lau, Lee, Abdullahi and Wong (2021) argued that 5D BIM modeling enables tracking of cost expenses and quantity level affected in construction project. 5D BIM enables the model to be used for the cost management in a construction project such as quality extraction, cost estimates, cost update, progress payment and many other model (Fariq, Ismail & Ab Rani 2022).

2.1.3 5D BIM Drivers

5D BIM drivers are factors that motivate and push the adoption and implementation of 5D BIM (Building Information Modeling) in the construction industry. Eastman et al. (2008) stated that, 5D BIM drivers includes efficiency that relates to the potential for improved productivity, reduced rework, and time savings through the construction project. Al-Momani et al. (2014) also explained that 5D BIM drivers involves collaboration, which enhances communication and coordination among project stakeholders. Cost drivers pertain to the potentials for cost savings and cost control achieved through accurate quantity takeoffs, cost estimation, and cost tracking using 5D BIM." (Bryde et al., 2018). Arayici et al. (2011) further explained that, 5D BIM drivers enhance construction quality, reduce errors, and improve overall project outcomes. 5D BIM drivers supports sustainability goals by facilitating energy analysis, life-cycle assessment, and environmental decision-making (Hassanain et al., 2015).

Nast and Koch (2021) stated that the critical success factor of 5D BIM implementation may be different, but certain partial costs cannot be overlooked in cost estimation. This partial cost includes the material costs, labour costs, expenses of the construction tools and indirect costs.

Cost drivers for efficient construction project delivery can vary depending on multiple factors, including project size, complexity, budget, and timeline. However, some common cost drivers for efficient construction project delivery include:

2.1.3.1 Planning and Design

Proper planning and detailed design documentation play a crucial role in keeping construction projects on track. Inadequate planning or design changes during construction can lead to costly delays and rework. Efficient planning and design management help identify potential issues in advance and allocate resources effectively (Bubshait & Al-Mubarak 2018). The planning and design driver refers to the ability of 5D BIM to support improved visualization, simulation, and analysis during the early stages of a project, enabling better decision-making and design coordination (Eastman et al., 2008). Arayici et al. (2011) further stated that, the design coordination driver emphasizes the use of 5D BIM to enhance coordination between different disciplines and stakeholders involved in the design process, reducing clashes and conflicts. The design optimization driver focuses on the use of 5D BIM to analyze and optimize design choices, considering factors such as cost, schedule, and sustainability performance (Wang et al., 2020).

2.1.3.2 Procurement and Supply Chain Management

Effective management of procurement and supply chain activities can minimize costs by ensuring timely delivery of quality materials at the best prices. Optimizing sourcing strategies, negotiating favorable contracts, and maintaining strong relationships with suppliers can reduce project costs (Bauchspiess, Lüthi, Frey & Ritzberger 2019). The improved procurement and material management driver emphasizes how 5D BIM can enhance procurement processes, including accurate quantity takeoff, material tracking, and supply chain management, leading to better cost control and efficient project delivery (Bao et al., 2016). In enhancing collaboration with suppliers and contractors, Succar et al. (2020) stated that The enhanced collaboration with suppliers and contractors driver highlights how 5D BIM can facilitate better communication and information sharing among project stakeholders, allowing for improved collaboration, reduced lead times, and better supply chain management. Li et al. (2017) also explained that, the cost optimization in procurement focuses on utilizing of 5D BIM to evaluate different procurement options, identify cost-saving opportunities, and optimize procurement strategies, resulting in better value for money and improved supply chain performance. Material tracking and delivery driver is also viewed under the supply chain management driver, Abanda et al. (2018) stated that, streamlined material tracking and delivery driver stresses the utilization of 5D BIM to track material quantities, logistics, and delivery schedules throughout the construction process, ensuring timely material availability, reducing waste, and enhancing supply chain efficiency. Another factor in procurement and supply chain management is the improved supplier integration and selection. Kang et al. (2019) explained that the improved supplier integration and selection driver discusses how 5D BIM can aid in selecting the right suppliers, evaluating their performance, and integrating them into the project supply chain, leading to better supplier management and project outcomes. Li, Soibelman, and Ge (2013) argued that, the integration of project management principles with BIM processes highlights that project management and collaboration tools help establish a shared understanding among team members, leading to improved decision-making and overall project performance.

2.1.3.3 Project Management and Collaboration

Effective project management techniques, such as clear communication, regular progress monitoring, and collaboration among stakeholders, ensure efficient utilization of resources and reduce the likelihood of costly errors or rework (Ibrahim Ali, & Othman 2017). Akintoye and Fitzgerald (2000) also stated that, project management and collaboration are crucial for successful implementation of technology-driven processes such as BIM. They emphasize the importance of effective communication, coordination, and cooperation between project team members to ensure project success. O'Brien and de Vries (2014) argue that effective project management practices, coupled with collaborative relationships, can enhance information sharing, streamline workflows, and improve decision-making throughout the project lifecycle. Shen, Hao and Liu (2010) also argued that that project managers need to develop effective strategies and processes, such as collaborative planning and coordination, to unlock the full potential of BIM in enhancing project outcomes. Zhang, Teizer, Lee and Eastman (2013) argued that, effective collaboration among project stakeholders facilitated by BIM can lead to better safety planning, hazards identification, and risk mitigation. According to Wu & Wang (2019), effective project management and collaboration facilitated by 5D BIM can lead to improved decision-making, cost estimation, and risk analysis. They emphasize the importance of integrating 5D BIM with project management processes to enhance project performance. Fayek and El-Diraby (2018) acknowledge the potential benefits of 5D BIM in enhancing collaboration and information sharing among project stakeholders. They argue that project management activities, supported by 5D BIM, can lead to improved cost control, scheduling, and resource allocation. Leicht (2020), focuses on the collaborative aspect of 5D BIM and its role in project management. He suggests that project managers can leverage 5D BIM capabilities to improve collaboration and coordination among team members, resulting in efficient decision-making and reduced risk. Lin and Liu (2018) discuss the importance of effective project management and collaboration in the context of 5D BIM adoption. They highlight that project managers should enhance their skills in utilizing collaborative tools and technologies to facilitate information exchange, decision-making, and conflict resolution among project participants. Verhoeven and Crombecq (2017), emphasize the necessity of project management approaches that facilitate collaboration in a 5D BIM environment. They argue that project managers should adopt a transformational leadership style to create a collaborative culture, fostering effective communication and coordination among project stakeholders.

2.1.3.4 Technology and Innovation

Adoption of advanced construction technologies, such as Building Information Modeling (BIM), prefabrication, and automated equipment, can enhance efficiency, reduce rework, and improve overall project delivery. Innovations in construction materials and processes can also lead to cost savings (Danilevičius Kvederytė & Bučinskas 2020). Zhang, Shen, and Jiang (2018) argue that technology and innovation play a crucial role in driving the adoption and implementation of 5D BIM. They highlight that emerging technologies, such as laser scanning, drones, and AI, can enrich the data-rich environment of 5D BIM, providing more accurate and comprehensive project information. Brilakis and Moon (2018), emphasize that technology advancements, particularly in the area of visualization and simulation, enable 5D BIM to enhance project performance. They discuss how virtual reality, augmented reality, and gaming engines can support better decision-making, construction planning, and clash detection in 5D BIM environments. Liu, Issa, and Chen (2019), state that innovation-driven technologies, such as cloud computing, big data analytics, and Internet of Things (IoT), can greatly enhance the utilization of 5D BIM. They argue that these technologies enable real-time data exchange, collaboration, and storage, leading to improved project management and decision-making. Al-

Hamdani, Wonorahardjo and Wibawa (2019), highlight that implementing 5D BIM requires organizations to adopt and innovate with new technologies, such as software applications, data integration platforms, and interoperable systems. They emphasize the need for continuous technology research and development to enhance the effectiveness of 5D BIM implementation. Al-Sallal and Dawood (2019), also assert that technology and innovation drive the transformation of construction practices through the integration of 5D BIM. They discuss how emerging technologies, such as mobile applications, remote sensing, and data analytic, contribute to improved project control, cost estimation, and collaborative decision-making in 5D BIM-enabled projects.

2.1.3.5 Risk Management

Identifying and mitigating potential risks throughout the construction project's lifecycle can help avoid costly delays, accidents, or disruptions. Effective risk management practices encompass proper insurance coverage, safety measures, and contingency planning (Liu, Hu & Chen 2020). Skibniewski, Meng, and White (2014), argue that risk management is a critical component of successful 5D BIM implementation. They highlight that 5D BIM enables better identification, assessment, and mitigation of project risks through integrated data analysis and visualization, leading to improved decision-making and project outcomes. Buso and Realfonzo (2017), emphasize that 5D BIM offers a comprehensive platform for managing project risks throughout the construction lifecycle. They state that 5D BIM's ability to integrate cost, schedule, and geometry data enables project teams to identify potential risks, assess their impacts on project objectives, and implement proactive mitigation strategies. Thabet, Al-Rashdan and Al-Malallah (2017), discuss that 5D BIM facilitates effective risk management by providing real-time and accurate project information. They argue that 5D BIM's integration of cost, schedule, and data visualization helps project teams identify and analyze risks, assess their impacts on project parameters, and develop appropriate response strategies accordingly. Kiviniemi, Mundani and

Cooke (2019), suggest that 5D BIM enables collaborative risk management among project stakeholders. They emphasize that 5D BIM's shared data environment allows for effective risk communication, analysis, and decision-making, fostering proactive risk identification and mitigation throughout the project's lifecycle. Alzahrani and Al-Bazi (2018), highlight that 5D BIM supports risk management by providing a dynamic platform for risk simulation and analysis. They discuss how 5D BIM's integration with other technologies, such as virtual reality and simulation tools, allows for real-time visualization and assessment of potential risks, helping project teams make informed decisions to mitigate those risks.

2.1.3.6 Improved Cost Estimation

5D BIM allows for more accurate and efficient cost estimation by connecting the project's 3D model with cost databases and real-time pricing information. This integration helps reduce errors and enables faster estimation of material quantities and costs. (Kiziltas & Kamat 2019). Stellingwerff and De Boer (2015), argue that 5D BIM enhances cost estimation by enabling the integration of accurate and up-to-date project information, including design data, quantity takeoffs, and cost databases. They state that the ability to visualize and analyze cost-related data in a 3D model context facilitates more accurate and efficient cost estimation, leading to improved project cost control. Görtz and Bartel (2014), highlight that 5D BIM improves cost estimation by allowing for more detailed and rapid quantity takeoffs. They emphasize that the automated measurement and calculation capabilities of 5D BIM software enable precise and consistent quantification of project elements, resulting in more accurate cost estimates. Yu, Wang, and Lu (2017), discuss that 5D BIM facilitates improved cost estimation through enhanced collaboration among project stakeholders. They argue that the shared data environment of 5D BIM allows for real-time communication and coordination, enabling better integration of cost-related information from different disciplines and supporting more accurate cost estimation throughout the project lifecycle. Mumovic, Sherif, and Chattat (2017), suggest that 5D BIM enhances cost estimation by enabling the analysis of cost implications throughout the design process. They highlight that the ability to link cost data with design components and performance parameters in a 5D BIM model facilitates early identification of cost drivers and enables iterative design optimization for better cost control. Anwar and McCartney (2018), emphasize that 5D BIM improves cost estimation by providing a platform for better data integration and analysis. They discuss how 5D BIM's ability to link cost data with 3D geometric and 4D scheduling information allows for more accurate quantity takeoffs and cost breakdowns, leading to improved cost estimation and control.

2.1.3.7 Enhanced Project Coordination

5D BIM facilitates improved coordination between different stakeholders involved in the construction project. It allows multiple teams (e.g., architects, engineers, contractors) to collaboratively work on a shared model, eliminating conflicts and reducing delays or rework (Zhang, Li & Wang 2020). Kanellopoulos and Nikolaou (2016), argue that 5D BIM improves project coordination by enabling the integration of time, cost, and spatial information. They emphasize that the visualization capabilities of 5D BIM foster better understanding and communication among project stakeholders, leading to improved coordination, reduced clashes, and increased efficiency in project execution. Safa, Alkhedhairi and Abdelrahman (2018), discuss that 5D BIM enhances project coordination through real-time collaboration and information sharing. They argue that the shared data environment of 5D BIM allows for effective coordination between different disciplines, facilitating early conflict detection, better decision-making, and smoother project execution. Ingirige and Aouad (2009), highlight that 5D BIM improves project coordination by enabling better integration and synchronization of activities across different teams and disciplines. They emphasize that the 5D BIM model serves as a central repository of project information, supporting real-time coordination, clash detection, and collaborative problem-solving, ultimately leading to improved coordination and project outcomes. Craig and Marsh (2012), suggest that 5D BIM enhances project coordination through improved visualization and clash detection. They discuss how the ability to visualize design elements in a 3D model, combined with time and cost data, enables project stakeholders to identify and resolve clashes, coordinate activities more effectively, and ultimately improve project coordination and delivery. Huang and Wang (2010), discuss that 5D BIM improves project coordination by facilitating collaborative planning and decision-making. They argue that the ability to simulate and analyze the construction process in a 5D BIM environment helps project teams identify potential coordination issues, evaluate alternative scenarios, and optimize construction sequences, leading to enhanced project coordination and productivity.

2.1.3.8 Efficient Schedule Planning

5D BIM enables real-time integration of project schedules with the 3D model, allowing 0stakeholders to visualize construction activities and their sequencing. This integration helps identify potential clashes, optimize resource allocation, and enhance project scheduling efficiency (Goodell & Durmisevic 2016). Arayici et al. (2011), emphasize that 5D BIM improves scheduling and planning by integrating time and cost information into the project model. They argue that the visual interface and data integration capabilities of 5D BIM enable a more accurate and efficient scheduling process, facilitating the identification of critical path activities, optimization of construction sequences, and improved project planning. Eastman and Sacks (2008), highlight that 5D BIM enhances efficient scheduling and planning by automating the generation of construction schedules based on the input of model components and associated attributes. They argue that the ability of 5D BIM to link geometry, quantities, timelines, and resources streamlines the scheduling process, reduces errors, and improves the accuracy of project plans. Liu and Issa (2017), discuss that 5D BIM improves scheduling and planning by providing a platform for collaborative planning and real-time schedule updates. They argue that the real-time integration of project data enables project stakeholders to visualize and analyze the impact of changes on the project schedule, facilitating better coordination, proactive decision-making, and efficient planning throughout the project lifecycle. Motamedi, Teizer and Behzadan (2013), emphasize that 5D BIM improves efficiency in scheduling and planning by facilitating the integration of construction process simulation with project information. They argue that the ability of 5D BIM to simulate construction activities and evaluate different scenarios enables project teams to identify potential issues, optimize schedules, and plan construction activities more efficiently, resulting in improved project planning and execution. Wang, Ahmad and Wang (2015), discuss that 5D BIM enhances scheduling and planning efficiency by enabling iterative and dynamic planning processes. They argue that the visual and interactive capabilities of 5D BIM facilitate the exploration of alternative planning scenarios, allowing project teams to optimize schedules, assess the impact of changes, and enhance the overall efficiency of project planning and coordination.

2.1.3.9 Accurate Quantity Takeoff

The use of 5D BIM streamlines the process of quantity takeoff by automatically extracting material quantities from the model, reducing manual effort and potential errors. Accurate quantity takeoff enables more precise cost estimation and better procurement planning (Banihashemi Ellingham & Sohn 2019). Arayici, Aouad, Cooper, Li and Wu (2019), state that accurate quantity takeoff is one of the fundamental benefits of 5D BIM. They argue that the ability to extract quantities directly from the virtual model improves the accuracy and efficiency of quantity takeoff processes, reducing errors and enhancing cost estimation. They emphasize that 5D BIM enables the automatic generation of detailed quantity reports, streamlining the bidding process and facilitating better decision-making. Chang, Lee and Messner (2014), highlight that 5D BIM enables accurate quantity takeoff by linking the geometric representation of building elements with associated properties and attributes. They argue that the parametric nature of 5D BIM ensures consistency and eliminates manual errors in quantity takeoff. They also emphasize that the intelligent object-based modeling approach of 5D BIM allows for automated measurement extraction, improving accuracy and reducing the time required for quantity takeoff. Fischer and Kunz (2004), discuss that 5D BIM enhances accurate quantity takeoff by providing a platform for integrated modeling and estimating. They argue that the interoperability of 5D BIM allows project teams to link quantity information directly to building elements, ensuring accuracy and consistency in quantity takeoff. They also emphasize that the visual representation of quantities in the 3D model enables better understanding and validation of the estimated quantities. Khosrowshahi (2010), discusses that 5D BIM improves the accuracy of quantity takeoff by minimizing errors associated with manual and disconnected processes. They argue that 5D BIM ensures a direct link between the model and the quantities, reducing discrepancies and improving the reliability of quantity data. They also emphasize that the transparency and traceability of 5D BIM support auditing and verification of quantity takeoff, enhancing accuracy and confidence in cost estimation. Succar (2009), highlights that 5D BIM enhances the accuracy of quantity takeoff by capturing and managing detailed information about building elements. They argue that the ability of 5D BIM to assign properties and attributes to model components enables the automated extraction of quantities, improving accuracy and reducing reliance on traditional manual takeoff methods.

2.1.3.10 Enhanced Project Visualization

5D BIM provides stakeholders with a visual representation of the construction project, helping them better understand the design intent, identify clashes, and make informed decisions. This enhanced visualization aids communication and reduces the potential for errors or misunderstandings (Elsawahli, Alhussan & Dawood 2018). Eastman, Teicholz, Sacks and Liston (2011), argue that enhanced project visualization is a key benefit of 5D BIM. They state that 5D BIM integrates time and cost data with 3D models, allowing project stakeholders to visualize construction progress and related costs throughout different stages. They emphasize that this visualization capability improves communication, coordination, and understanding among project team members, leading to better decision-making and more effective project management. Feeney, Liu and Lee (2018), suggest that enhanced project visualization offered by 5D BIM facilitates effective communication and collaboration among project participants. They argue that the integration of cost and schedule information with a 3D model enables visual analysis of how changes in design or schedule impact the project's cost and timeline. They emphasize that this visual representation enhances stakeholder engagement, supports informed decision-making, and leads to improved project outcomes. Lee and Kim (2016), highlight that enhanced project visualization through 5D BIM allows stakeholders to better understand the project's scope, sequence, and cost implications. They argue that the visualization of construction activities, resources, and associated costs using 5D BIM enables project teams to identify potential conflicts, inefficiencies, and cost-saving opportunities. They emphasize that this visual representation fosters effective collaboration and enables proactive decision-making to optimize project performance. Agrawal and Maheshwari (2018), discuss that enhanced project visualization provided by 5D BIM enhances stakeholder engagement and allows for improved project planning and execution. They argue that visualizing the project schedule and cost information within the 3D model aids in identifying clashes, conflicts, and potential delays, leading to proactive planning and mitigation strategies. They also emphasize that this visual representation helps in generating accurate and comprehensive reports for effective project performance monitoring. Barrett and Stanley (2010), propose that enhanced project visualization enabled by 5D BIM improves understanding and promotes collaboration in construction projects. They argue that visualizing time, cost, and design elements together aids in identifying potential risks, constraints, and conflicts at an early stage. They emphasize that this multidimensional visualization provides a shared platform for stakeholders to communicate, assess, and refine project plans, thereby improving project outcomes.

2.1.3.11 Real Time Monitoring

Zhang and Wang (2015), suggest that real-time monitoring is a significant benefit of 5D BIM. They argue that by integrating real-time data from various sources (e.g., sensors, equipment, and workers) with the 5D BIM model, project teams can monitor construction progress, resource utilization, and performance. They emphasize that this real-time monitoring capability enables project stakeholders to proactively identify and address issues, ensure project quality and efficiency, and make informed decisions in a timely manner. Lu and Issa (2018), discuss that real-time monitoring, made possible by 5D BIM, enhances project control and reduces risks. They argue that by integrating sensor data and monitoring systems with the 5D BIM model, project teams can monitor parameters such as temperature, vibration, and structural behavior in real-time. They emphasize that this monitoring allows for early detection of deviations or anomalies, facilitating timely interventions, and reducing potential delays or hazards. Gu and Wei (2017), highlight that real-time monitoring through 5D BIM is crucial for ensuring project progress and quality. They argue that integrating real-time data on construction activities, equipment, and material usage into the 5D BIM model enables project managers to monitor the current status of the project and compare it with planned schedules. They emphasize that this monitoring capability helps identify potential deviations, delays, or conflicts, supporting effective decision-making and project control. Pan, Pan and Zhao (2020), suggest that real-time monitoring is a key advantage of 5D BIM, bringing benefits for both project management and stakeholder engagement. They argue that by integrating real-time data from construction sites, IoT devices, and mobile devices with the 5D BIM model, project teams can monitor and track construction activities, worker productivity, and equipment utilization. They emphasize that this real-time monitoring enhances project transparency, collaboration, and communication, leading to improved project outcomes. Hartmann and Fischer (2019), state that real-time monitoring facilitated by 5D BIM enables project teams to track and manage construction progress continuously. They argue that by integrating on-site data collection systems (e.g., drones, cameras, and sensors) with the 5D BIM model, project managers can visualize the real-time status of work, identify bottlenecks, and monitor resource consumption. They emphasize that this real-time monitoring capability supports adaptive planning, timely decision-making and improved project performance.

2.1.3.12 Enhanced Communication

Olatunji and Sher (2018), argue that enhanced communication is a key benefit of 5D BIM implementation. They suggest that by integrating project data into a central 5D BIM model, project stakeholders can access and share information in a collaborative and transparent manner. They emphasize that this enhanced communication facilitates effective coordination, reduces misunderstandings, and improves decision-making, leading to improved project outcomes. Cardoso and Silva (2017), highlight that 5D BIM enhances communication among project stakeholders through the visualization and simulation capabilities it offers. They argue that by visualizing project data (e.g., design, cost, and schedule) in a 3D environment, project teams can communicate complex concepts more effectively. They emphasize that this enhanced communication enables stakeholders to better understand the project and collaborate more efficiently, resulting in improved project coordination. Alshennawy and Alalawneh (2019), suggest that 5D BIM enhances communication and collaboration among project teams and stakeholders. They argue that the centralized 5D BIM model allows project participants to access and share up-to-date information in a standardized format. They emphasize that this enhanced communication streamlines information exchange, facilitates coordination, and reduces errors in decision-making, leading to improved project performance. Mahalingam and Behm (2020), discuss that 5D BIM improves communication through its ability to integrate and link project data. They argue that by connecting cost and schedule information with the 3D model, project teams can communicate the impact of design changes on project cost and schedule more effectively. They emphasize that this enhanced communication supports collaborative decision-making, enables early identification of conflicts or delays, and improves project coordination and control. Hope and Foster (2018), emphasize that 5D BIM enhances communication by providing a common platform for project stakeholders. They argue that the shared, real-time 5D BIM model allows project teams to communicate and exchange information efficiently. They emphasize that this enhanced communication fosters collaboration, aligns project participants, and improves project coordination and delivery.

2.1.3.13 Resource Allocation

Li and Lu (2015), argue that 5D BIM enables enhanced resource allocation in construction projects. They suggest that by integrating cost and schedule data with the 3D model, project teams can visualize and analyze the allocation of resources throughout the project lifecycle. They emphasize that this capability allows for better resource planning, optimization, and coordination, leading to improved project efficiency and cost control. Kim and Kim (2017), highlight that 5D BIM facilitates effective resource allocation in construction projects. They argue that the integration of design, cost, and schedule information in a central 5D BIM model provides project teams with a comprehensive view of resource requirements. They emphasize that this integrated approach allows for early identification of resource conflicts, improves resource utilization, and supports informed decision-making regarding resource allocation. Negreira and Oviedo (2019), discuss that 5D BIM enhances resource allocation through its ability to integrate project data. They suggest that by connecting cost and resource information with the 3D BIM model, project teams can accurately plan and allocate resources. They emphasize that this integration enables real-time monitoring of resource usage, facilitates resource optimization, and supports dynamic adjustments to resource allocation during the project. Rezgui, Clements-Croome and Li (2019), highlight that 5D BIM improves resource allocation in construction projects. They argue that the integration of cost, schedule, and 3D information allows project teams to assess resource requirements accurately. They emphasize that this integrated perspective on resource allocation enables proactive planning, supports effective resource utilization, and facilitates coordination among project teams, leading to improved project performance.

2.1.3.14 Change Management

Dawood and Koskela (2013), argue that 5D BIM can significantly improve change management in construction projects. They suggest that by integrating design, cost, and schedule data, 5D BIM facilitates real-time tracking and visualization of changes. They emphasize that this capability enables project teams to assess the impact of changes on cost and schedule, identify potential conflicts, and make informed decisions regarding change management. Dikbas and Scherer (2017), discuss that 5D BIM enhances change management practices in construction projects. They argue that the integration of design, cost, and schedule information enables project teams to identify and address change requests more effectively. They emphasize that this integrated approach supports efficient change evaluation, improves change control and coordination among project stakeholders, and minimizes disruptions caused by changes in project scope. Lu and Wang (2018), highlight that 5D BIM plays a crucial role in change management in construction projects. They suggest that the multidimensional nature of 5D BIM enables project teams to evaluate changes comprehensively, including their impact on design, cost, schedule, and resources. They emphasize that this comprehensive evaluation empowers project stakeholders to make well-informed decisions about change management, leading to reduced change-related issues and improved project performance. Rollo and De Toni (2019), discuss that 5D BIM fosters effective change management in construction projects. They argue that by integrating different project dimensions, 5D BIM provides a holistic view of the project and supports the timely identification, analysis, and resolution of changes. They emphasize that this holistic perspective enhances change control, enables proactive change management, and improves project outcomes.

2.1.3.15 Heightened Cost Forecasting

Arayici, Hamilton, Gamito, and Harty (2011), discuss that 5D BIM enables improved cost forecasting in construction projects. They argue that by integrating 3D model information with cost data, project teams can visualize and analyze cost implications at every stage of the project. They emphasize that this integrated approach to cost forecasting supports more accurate predictions, better cost control, and early identification of potential cost overruns. Alsharif and Baharuddin (2016), emphasize that 5D BIM enhances cost forecasting capabilities in construction projects. They suggest that by linking the 3D model with cost information, project teams can simulate different scenarios and evaluate their cost implications. They argue that this simulation-based approach enables more accurate cost forecasting, better understanding of cost drivers, and improved decision-making throughout the project lifecycle. Azhar, Hein and Sketo (2018), discuss that 5D BIM plays a significant role in improving cost forecasting in construction projects. They argue that by integrating design, cost, and schedule data, project teams can perform cost simulations, track cost changes in real-time, and forecast cost deviations more accurately. They emphasize that this integrated approach enhances project control and enables proactive cost management, leading to better cost forecasting and improved project performance. Cunningham, Robinson and Kehily (2020), highlight that 5D BIM enables heightened cost forecasting in construction projects. They suggest that the integration of design, cost, and schedule information facilitates more accurate estimation and tracking of project costs. They argue that this integrated approach supports proactive cost forecasting, early identification of cost variances, and better cost control, resulting in improved project cost performance.

2.1.3.16 Shorter Project Life Cycle

5D BIM can significantly contribute to a shorter project life cycle. The integration of 3D models with time and cost data enables project teams to improve the planning and sequencing of activities. They suggest that this integration facilitates better coordination, reduces rework and conflicts, and ultimately leads to smoother project execution and shorter overall project duration (Eastman, Teicholz, Sacks & Liston 2011). Mourshed, Matipa, and Awodele (2018), discuss that 5D BIM supports the achievement of shorter project life cycles. They emphasize that the ability to visualize and simulate construction processes using 5D BIM enables project teams to identify potential bottlenecks and optimize project schedules. They argue that this optimization helps to streamline project execution, reduce delays, and ultimately deliver projects in a shorter time frame. Porwal and Hewage (2019) suggest that 5D BIM can contribute to shorter project life cycles by enhancing construction planning and execution. They discuss that the integration of 3D models, time, and cost information in 5D BIM allows for better coordination, improved task sequencing, and efficient resource allocation. They argue that these benefits lead to reduced project durations, improved productivity, and shorter project life cycles. Gursansky and Smith (2020), emphasize that the use of 5D BIM can significantly accelerate project life cycles. They suggest that the integration of design, time, and cost information facilitates better decision-making and allows for faster project execution. They argue that this integration enables project teams to identify and resolve issues early, avoid potential delays, and ultimately deliver projects in a shorter time frame.

2.1.3.17 Multi-Platform Access

Many authors argue that multi-platform access promotes better collaboration and integration among project stakeholders by enabling real-time sharing of BIM data across different tools and platforms. Multi-platform access extends the benefits of BIM by enabling real-time collaboration and integration among different stakeholders, resulting in better decision-making and project outcomes (Eastman et al., 2011). Other authors argue that multi-platform access enhances flexibility and interoperability by allowing different software tools to exchange data seamlessly in a BIM environment. Multi-platform access ensures better interoperability among software tools, allowing project teams to work with their preferred BIM software while seamlessly exchanging data (Azhar, Khalfan, Maqsood, & Mbachu 2011). Although, other authors acknowledge the challenges associated with multi-platform access, such as data inconsistency, compatibility issues, and the need for better data standards to ensure the effectiveness of multi-platform collaboration. Ullman, (2014), stated that the lack of standardized data formats and interoperability between different software tools remains a significant challenge in achieving efficient multi-platform access.

2.1.3.18 Early Involvement of Contractors

Salvadori (1980), In his book "Why Buildings Stand Up," Salvadori emphasizes the importance of involving contractors early in the design process to improve constructability, reduce costs, and enhance overall project outcomes. The benefits of early contractor involvement in 5D BIM, suggesting that it leads to better coordination, reduced project delays, and cost savings (Ghafari et al., 2011). Eastman et al.(2011) In the book "BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors," Eastman et al. discuss the advantages of involving contractors early in the design process, stating that their valuable input helps in refining the construction sequence, cost estimation, and reducing conflicts during construction. Mordue (2009), in his paper titled "Working Towards a Web-Based Integrated Building Design System" argues that involving contractors early in the design process through 5D BIM allows for better communication, improved constructability review, and enhanced project planning.

2.1.3.19 Clash Detection and Clash Avoidance

Frewer, Arnaout and Whyte (2016), in their paper "Construction Clash Management Approaches with Clash Detection and Avoidance Techniques," the authors discuss the importance of clash detection and avoidance in 5D BIM. They argue that early clash detection and effective clash management can reduce rework, improve project scheduling, and overall project delivery. Bani-Hani and Dahnoun (2018), stated in their research article titled "Automated Clash Detection and Management in Construction Projects Using BIM," the authors emphasize that 5D BIM's clash detection and management capabilities enable early identification of clashes, leading to more accurate cost estimation, improved safety, and reduced construction delays. He, Ding, and Chen (2020), highlighted the significance of clash detection in complex construction projects. They suggest that proactive clash detection and resolution using 5D BIM can minimize rework, enhance project efficiency, and reduce construction costs. Thurairajah, Yahya and Hon (2020), in their book chapter "Virtual Design and Construction: Clash Detection and Avoidance," the authors discuss the benefits of clash detection and avoidance as a 5D BIM driver. They discuss how clash detection can help in identifying and resolving design conflicts, improving project coordination, and minimizing construction issues.

2.1.3.20 Construction Schedule Optimization

Chen, Kong and Chien (2019), in their research article titled "Construction Schedule Optimization Considering BIM-Based Spatial Constraints," the authors emphasize the benefits of using 5D BIM for construction schedule optimization. They argue that 5D BIM enables improved coordination, visualization, and clash detection, ultimately leading to more efficient construction schedules. Some authors highlighted the advantages of employing 5D BIM for construction schedule optimization. This has led to how 5D BIM allows for the integration of design and construction information, enabling accurate visualization, coordination, and sequencing of construction activities (You et al., 2018). 5D BIM enables integration of cost and schedule information, facilitating the identification of conflicts and optimization of construction sequencing (Motamedi et al., 2020). Sermet, Noushad and Elvin (2016), in their article "Utilizing Building Information Modeling for Optimization of Construction Schedules," the authors present the viewpoint that 5D BIM can effectively optimize construction schedules. They discuss how 5D BIM allows for the visualization and simulation of construction activities, enabling early identification of schedule conflicts and various what-if scenarios.

2.1.3.21 Clear Project Objectives and Scope Definition

Zhang and Chen (2019), argue that 5D BIM can contribute to setting clear project objectives and scope by providing a digital platform for stakeholders to effectively communicate, visualize project components, and ensure everyone's understanding and alignment. A well-defined project scope is essential for successful implementation of 5D BIM. This emphasizes the importance of setting clear project objectives and scope from the beginning, as it forms the foundation for effectively utilizing 5D BIM throughout the construction process (Zhang et al., 2019). San, M. Tan and Shan (2019), in their research article "Research on the Application of 5D BIM Technology in Construction Project Management," the authors highlight the role of 5D BIM in ensuring clear project objectives and scope definition. They assert that 5D BIM enables stakeholders to have a shared understanding of the project, aiding in the identification of project goals and scope, thereby enhancing communication and collaboration.

2.1.3.22 Availability of Accurate and Updated Project Information

5D BIM enables real-time data integration and visualization, providing stakeholders with accurate and up-to-date information, which improves decision-making and project control (Liu et al., 2019). Wang and Min (2016), in their study titled "The Optimization of 5D BIM-Based Construction Project Management," the authors discuss the importance of accurate and updated project information for effective construction project management with 5D BIM. They suggest that 5D BIM facilitates the integration and management of project data, ensuring that accurate information is readily accessible to all stakeholders, consequently enhancing project coordination and collaboration. Longo et al. (2019), in their research article "Information Management Systems: Enhancing Project Performance in Construction via BIM and H&S Integration," the authors emphasize the role of 5D BIM in providing accurate and updated project information. They assert that 5D BIM offers a central repository of project data, allowing stakeholders to access and update information in real-time, which improves overall project performance.

Table 2.1: Categories of 5D BIM Drivers

CATEGORY	5D BIM DRIVERS	Authors
Management	D.01 Planning & Design	(Bubshait & Al-mubarak 2018).
	D.02Procurement & Supply chain management	(Bao et al., 2016).
	D.03 Project management collaboration	(Ibrahim Ali, & Othman 2017).
	D.04 Enhanced project coordination	(Zhang, Li & Wang 2020).
	D.05 Efficient scheduling planning	(Goodell & Durmisevic 2016).
	D.06 Resource allocation	(Li & Lu 2015)
	D.07 Change management	(Dawood & Koskela 2013)
	D.08 Shorter project life cycle	(Mourshed, Matipa, & Awodele 2018)
	D.09 Early involvement of contractors	(Mordue 2009)
	D.10 Construction schedule Optimization	(Chen, Kong & Chien 2019)
	D. 11 Clear project objective and scope definition	(Zhang & Chen 2019)

Technical	D.12 Technology innovation	(Zhang, Shen, & Jiang 2018)
	D. 13 Risk management	(Skibniewski, Meng, & White 2014)
	D.14 Enhanced project visualization	(Elsawahli, Alhussan & Dawood 2018)
	D.15 Real time monitoring	Lu & Issa (2018)
	D.16 Enhanced communication	(Olatunji & Sher 2018)
	D.17 Multi platform access	(Azhar,Khalfan, Maqsood, & Mbachu 2011)
	D.18 Clash detection and clash avoidance	
	D.19 Availability of accurate and updated project information.	(Wang & Min 2016)
Financial	D.20 Improved cost estimation	(Kiziltas & Kamat 2019).
	D.21 Accurate quantity take-off	(Banihashemi, Ellingham & Sohn 2019).
	D.22 Heightened cost forecasting	(Arayici, Hamilton, Gamito, & Harty 2011)

Source: Author's compilation 2023

In the above table, the already discussed 5D BIM drivers were categorized into three, the management category, the technical category and the financial category where each of the already discussed twenty two drivers are allocated to its accurate category.

2.1.4 5D BIM Implementation

Zaman (2022) stated that, the progress in cost capabilities is gradually gaining speed and major projects cost management industries and companies are realizing the competitive advantage in the adoption of this "new age" way of cost management. In the year 2008, in the United States (US), a major driver in the profession using 5D BIM occurred. To mitigate the cost of related problems in facility industries under the building alliance, the association for the advancement of cost engineering international (AACE), The American society of professional estimators (ASPE), the army corps of Engineers, the general services administration (GSA), and the National institute of building services (NIBS) agreed to collaborate. The aim was to form a system and protocols for the collaboration and coordination in a project throughout its entire life cycle.

In 2012, new guidelines emerged and known as Black book (Quantity Surveyors and construction standards) and new rules of measurement (NRM) was published by the royal institution of chartered surveyors (RICS). The black book consists of compiled and comprehensive documents that explained good technical standards for construction and quantity surveying rather new rules of management was linked fundamentally within 5D BIM and it has allowed a continuous way of estimation and cost planning within platform (Smith 2016).

2.1.4.1 5D BIM Implementation Advantages

5D BIM is a valuable information platform not only during construction process, but also through the entire projects lifecycle. This is to say BIM shares and modernize the drawings and specifications with ease and simplicity in cloud data base, and then the 5D BIM which is related to cost forms a precise estimation of construction and project cost BIM serves as a tool that enables the sharing of information between the users and stakeholders in a construction industry with very effective, smooth and very quick to minimize mistakes and extra workload (Grilo &

Goncalves 2010).Moreso, 5D BIM presents all stakeholders in construction industry with a clear budget and construction progresses(Settineni & Jennifer 2014).

Furthermore, 5D BIM has more effectiveness in time management for alternative design analysis and other decisions at the early stage of a construction project. 5D BIM usually performs the cost analysis and management in other software and or application. 5D BIM includes all relevant information and data not only in a small period, but also in the long run to manage and monitor the projects (Mesaros, Smetankova & Mandicak 2019).

2.1.4.2 5D BIM Implementation Challenges

Most of the difficulties encountered in the implementation of 5D BIM are related to software security, investment in training, less efficiency time, not up to the par standards of software appropriability (Mesaros, Smetankova & Mandicak 2019). Settineni and Jennifer (2014) also mentioned that the 5D BIM implementation always require high initial costs and need new skilled expertise and experience which includes computer experts, as compared to typical and less automated construction even though companies don't want to embarace modernization.

Another challenge of 5D BIM it it's low Level of Development (LOD), which could not extract in-depth information from the 3D BIM model regarding cost estimation. Aibinu and Venkatesh (2014) opined that there are so many problems of 5D BIM which is used by the quantity surveying organizations, such as the low LOD of a model. Hence, because of the less availability of detailed information, the team takes more time to make sure that the quantity takeoff is precise and accurate.

Usually, 5D BIM or BIM software does not fit for the depth quantity takeoff, for example, cladding tasks, since architects and designer often provide many details to the drawings rather than to the models and mostly subcontractors companies use BIM only for visualization of a model in 3D and some of subcontractor companies do not share their models with other construction teams. Unnecessary and extra work is likely to happen due to lack of communication and incompatible drawings and there maybe mis match between design drawings and specifications which happens due to mistakes or missing data and subsequently leads to wrong calculations and estimation of cost (Mayouf, Gerges & Coz 2019).

More so the errors of the model may not be revised timely, so the accuracy of the quantity takeoff will be affected (Wu, Wood, Ginige & Jong 2014). Mayouf further stated that the 5D BIM implementation needs a big and collective flow of work and data where one of the restrictions of cost estimation work is the bad documentation quality, multidisciplinary and collective approach plays a vital role in improving the efficiency of communication and the quality of documentation.

2.1.5 5D BIM Use Cases

2.1.5.1 Quantity Takeoff

There are research papers in which the quantity takeoff has been defined and described in so many ways in terms of the improvements in Building Information Modeling (BIM) where Stanley and Thurnell (2014) have come up with their research with research consultants that in order to have quantity takeoff, the use of BIM models has increased the efficiency and fastened the creation of construction material schedules providing that the information provided in the model is appropriate. Nadeem, Wong and Wong (2015) have found out that the use of bills of quantities, in addition to a 3D model of the same quantities not only increases the efficiency and accuracy of BOQs (Bill of Quantities) but also increases the overall understanding of the project. Monteiro and Martins (2013) discovered that some quantities cannot be taken out directly from the 3D models because of capabilities of currently available tools, the detail provided in the model, or in other words few elements are not modeled. Therefore, estimators and quantity surveyors would certainly be needed to extract quantities from the 3D model's available data or aggrandize the models by providing the missing information in the model up to their experience and knowledge to validate the derived information (Chuck, Teicholz, Sacks & Listra 2011).

2.1.5.2 Cost Estimating

In addition to the quantity take-off capabilities of 5D BIM solutions, the cost estimating applications of 5D BIM tools allow the formation of cost estimates that show more accuracy to the actual cost of the project (Azhar 2011) and overall abatement of the costs as stated by (Bryde, Broquetas & Volm 2013). The exercise of quantity take-off tool as explained by (Chuck 2011) corresponds to the application of a constant quantity take-off tool to take out the quantities as mentioned earlier.

2.1.5.3 Cost Budgeting

To get the actual project's outcome, the linking of a model to the costing database enables the estimators to investigate the possible costing and resources management processes and tools (Popov, Juocevicius, Migilinskas, Ustinovichius & Mikalauskas 2010). Through this way, a better understanding for and by the client could be generated and it also impacts the decision on costs (Olatunji Sher & Gu 2010).

2.1.5.4 Cost Control

Throughout the whole life cycle of the project, the cost control must be performed regularly with the help of analyses from different economic indicators. 5D BIM tools of different capabilities allow rapid and effective cost control processes, which includes the following:

With respect to Cash flow forecast, Kim and Francois (2010) have defined in their research that cash flow analyses are automatic with the use of 5D BIM, allowing for rapid and more effective cash flow forecasts in the project's early phase of the life cycle. Lu, Wan and Cheng (2016) have moreover created a frame work that, when the connection with 5D BIM is generated, users are allowed to construct the complex and detailed payments and contract structures to improve the accuracy of the forecasts. Afterward, the cash flow analyses could be easily modified when any changes occurred in a project.

The cost-to-date compared with budget and anticipated final cost is another process. The faster evaluation of the cost to date is possible by creating the link between the model and the contractor's rates and prices information by fixing the already completed model elements and dividing them by trade (Mitchell 2012). To check the differences between actual cost and budget, the information between model and contractor can be compared and it helps not only in the identification of most cost impacting elements but also gives its input in finding the probable final cost of the project (Chuck, Teicholz, Sacks & Listra 2011).

Change orders management is another costing process. The probable change in total costs of the project could be easily and rapidly evaluated with the help of the dynamic link between the model and costing information (Mitchell 2012), by creating multiple accurate simulations before the construction of elements (Yaicinkaya & Arditi 2013). The progress in level of development throughout the project's life cycle also enables the users to evaluate changes more accurately, precisely, and timely (Smith 2016).

2.1.6 Types of Digital Cost Management

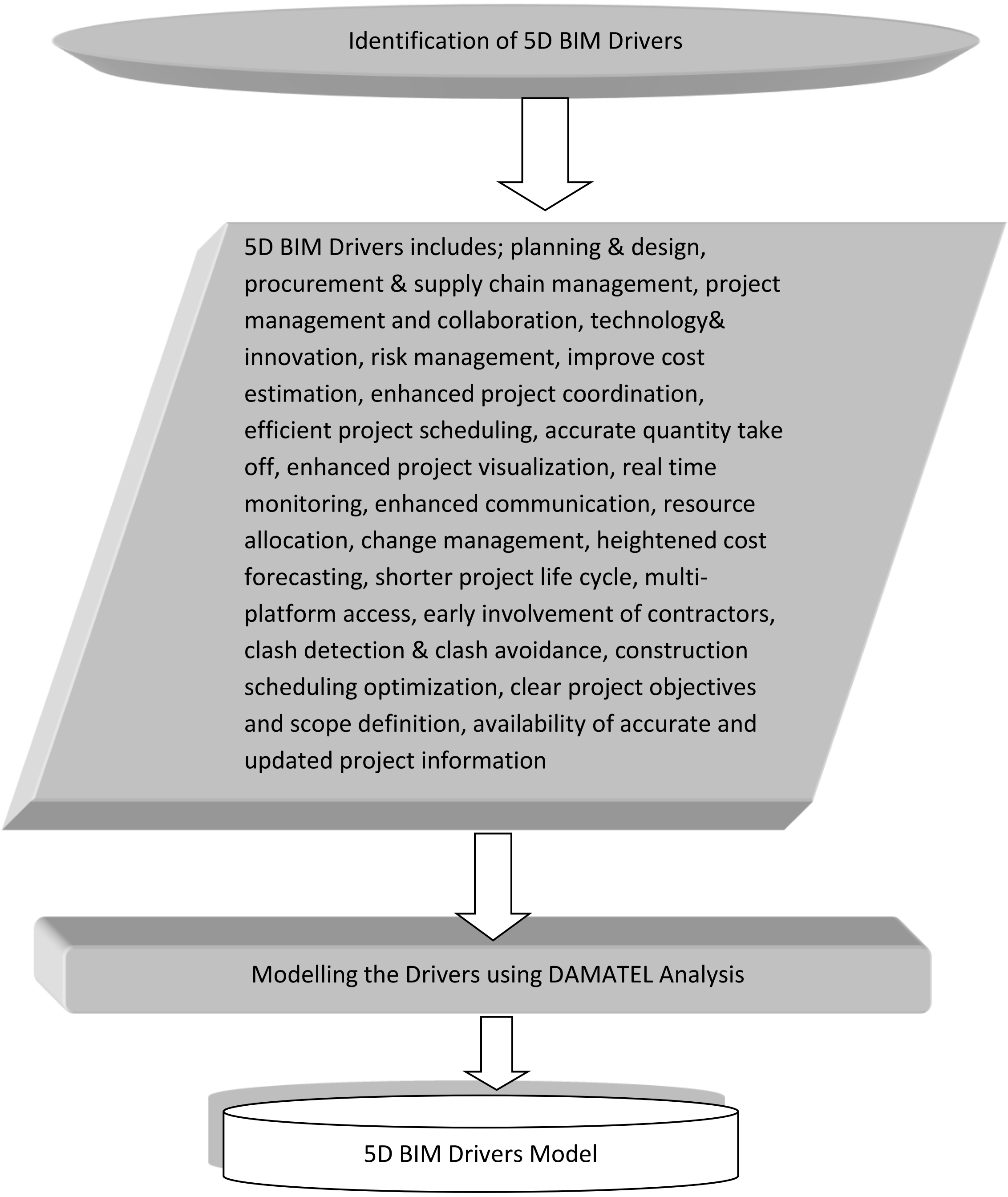
Lu, Lai and Tse (2019) stated that there are three main digital cost management which includes, exporting quantities to the traditional software, bridging BIM design tool with cost management software and using 5D BIM based cost management applications. The first type which is exporting quantities to the traditional software is the most used in organizations. The software includes, CAD Reader, Dimension X 2D, e Takeoff and many more. The advantage of this method is that the cost is not very expensive, other software application like the Microsoft Excel, which is widely used in cost managing of construction projects are not very difficult to be used.

The second type is bringing BIM design tools with cost management software are gradually becoming known to organizations. Applications such as Autodesk Revit are the most recommended and used, though some few plug-ins such as Tacoman iLink supports this method. Currently, few digital cost solutions such as Cubicost TAS, Autodesk Takeoff and Vico office are widely accepted in this type. The third cost management application type which manages and analysis cost within the model itself. Example is Cubicost by Glodon which integrates measurement applications type that supports various standards of measurement (SMM) with its own cost data management application that enables the user to have complete BIM 5D solutions.

Shen (2022), also stated that the 5D BIM model is not only a 5D platform but also compatible with other non-BIM platform software package such as GCL graphic quantity calculation software and project calculation construction schedule preparation software in the construction of BIM file. Presently, the commonly used modeling software includes Revit, CATIA, Archi CAD, Bentley and other series of BIM software.

2.1.7 Conceptual Framework

A conceptual framework is simply a tool that organizes and explain the relationship between different concepts and ideas. With respect to his research, the conceptual framework will see the relationship between identification of 5D BIM drivers, the identified derivers, modeling of the drivers using DAMATEL analysis and lastly 5D BIM drivers model as seen below.



Source: Authors compilation 2023

Figure 2.1: conceptual framework

2.2 Theoretical Review

Theoretical review is an essential component of scientific research as it allows researchers to critically analyze and synthesize existing theoretical perspectives and concepts related to the study. Smith et al. (2010) stated that, theoretical review enables researchers to identify existing gaps in knowledge, inconsistencies and conflicts in theoretical frameworks and to refine their own research questions. By examining various theoretical perspectives, researchers can choose the chose the most appropriate theoretical framework to guide their study, ensuring that their research is built on a solid foundation.

2.2.1 Technology Acceptance Model Theory (TAM)

Technology acceptance model (TAM) has been based on Theory of Reasoned Action (TRA) and has been used to explain individual's acceptance behavior. Technology acceptance model theory was first proposed by Davis (1989) in his doctoral thesis. The theory which is theory of planned behavior helps to recognize how the behavior of people can be changed.

A number of critics have been discussed in relation to Technology acceptance model its extension over the years. These criticisms includes the simplicity of TAM and lack of understanding of the antecedents of technology acceptance which includes perceived usefulness and perceived ease of use, were the subjects of criticism (Marikyan, D. & Papagiannidis, S. 2023).

Alawadhi et al. (2015) examined the adoption of BIM in small and medium-sized construction enterprises in Qatar and applied TAM to identify key factors influencing the acceptance and implementation of BIM technology. Radujković, Mladenović and Šajter (2018), stated that to assess the acceptance of BIM technology using TAM. Certain factors, such as perceived usefulness, perceived ease of use, and compatibility as influential in BIM adoption. Love, Mandal and Li (2016), examined the determinants of BIM adoption in the construction industries of Australia, Canada, and the United Kingdom. Their study incorporated TAM and identified factors such as relative advantage, compatibility, and trial-ability as important drivers of BIM adoption. Wang and Koskela (2009), explored BIM adoption and implementation in architectural practices and proposed an extended TAM framework specific to the architectural context. Their research emphasized the significance of factors such as perceived ease of use, organizational readiness, and training in BIM acceptance. Song (2015), argued that the successful implementation of BIM in construction firms and incorporated TAM as part of the change management process. The study highlighted the importance of user acceptance and identified factors such as perceived usefulness and compatibility as critical in BIM implementation.

Technology acceptance model (TAM) theory is a model that looks at how people accept and use new technologies. It suggests that people are more likely to use a new technology if they believe it will be useful and easy to use. In the context of 5D BIM, this means that if construction teams believe that 5D BIM will be useful and easy to use, they will be more likely to adopt it. There's actually been some research that's looked at this relationship specifically, and it found that there's a positive correlation between TAM factors and 5D BIM adoption.

2.2.2 Lean Theory

James et al. (1978), stated that the concept of lean theory also known as lean manufacturing or lean production system was originally developed by the Toyota motor corporation in Japan. The concept was first introduced by Taiichi Ohno, a Toyota engineer, in the 1950s. Ohno's work shaped the foundation of the lean philosophy, which emphasizes the elimination of waste and the continues improvement of processes. Donna (2013) identified five criticisms of lean as stated by various authors which includes critics on the style and narrative device of the machine, the empirical evidences contained in the machine, the effects of lean on the workforce or the exploitation, the transfer and universal application claims of lean and the financial benefits of lean. With regards to the first critic, Delbridge (1995) was critical of the arrogance of such claims which he dismissed as generalized simplifications based on stereotypes and western misconceptions. With regards to the second critic. Coffey (2006) questioned the historic accuracy of the machine. Gill (2003) with respect to the third critic found out that lean leads to elevated stress levels, increased worker turnover, absenteeism and time loss due to accidents. The forth critic as stated by Cooney (2002) described the claimed universality of the lean production concept as a chimera, arguing that lean is an addition rather than a replacement for existing production system. In the last aspect, Darlington et al. (2008) stated that lean accounting has become the foremost topic of discussion amongst lean practitioners over the past years.

Dawood, Sikka and Iqbal (2018), evaluate the theory and practice of lean construction and highlight its potential benefits for the construction industry, such as improved project delivery, reduced waste, and enhanced productivity. Al-Zahrani and Al-Dohaiman (2019), investigated the factors that influence the successful implementation of lean construction in the Saudi Arabian construction industry, emphasizing the need for a change in management mindset and cultural transformation. Formoso, Isatto and Guerrini, (2017), also examine the diffusion of lean production concepts in construction and assess their impact on productivity. The study highlights the importance of understanding lean principles and their application to maximize productivity gains.

Lean theory is a set of principles that are focused on reducing waste and maximizing value. In the construction industry, lean principles can be used to streamline processes and improve efficiency. So, there's a clear connection between lean theory and 5D BIM, since 5D BIM is all about reducing waste and improving efficiency in construction projects. In fact, there's a concept called "integrated lean and BIM," which combines the principles of both lean and BIM to maximize their benefits.

2.2.3 Social Network Theory

Social network theory was first introduced in the 1890s as a study on the structure of the society. Social networking theory was popularized by Jacob Moreno in 1932 and has since been applied in various disciplines. Wellman (1988) criticizes the theory and stated that the social network theory only focuses on relationships among actors as an explanation of actor and network outcome. This is in contrast to the traditional dispositional or individualist explanations that focuses on attributes of actors that are treated as independent cases. Lorenz (1963) also stated that society does not consist of individuals, but expresses the sum of interrelations in which individuals stand with respect to one another.

Davies and Mackenzie (2010), in his article titled "Social network theory and the construction industry", explore the role of weak ties in social networks within the construction industry, highlighting their importance for knowledge sharing, innovation, and collaboration. Faniran (2003), examines the impact of social networks on cooperation in the construction industry, finding that strong ties facilitate cooperation among project participants and enhance project performance. Halman, Song and Voordijk (2009), in his work titled "Social capital in project-based construction networks: A multi-level analysis" analyzed social capital within project-based construction networks, emphasizing its influence on communication, trust, and collaboration among project stakeholders. González-Rodríguez and Fuentes-Bargues (2019), employed social network analysis to evaluate knowledge sharing dynamics in construction projects, demonstrating how network characteristics influence knowledge flow and project performance. Manu and Malone (2018), also use social network analysis to understand project performance in construction projects, revealing the impact of network structures, tie strengths, and centrality on project success.

Social network theory is a way of looking at the relationships between people or organizations in a network. In construction, this could mean looking at the relationships between project stakeholders, such as contractors, subcontractors, owners, designers, and so on. So, social network theory can be applied to 5D BIM to understand how the different stakeholders interact and collaborate in a project. The goal is to optimize the network and improve communication and collaboration, which can lead to better outcomes for the project.

2.3 Empirical Review

The empirical review of this study will refer to various studies conducted by many other researchers relating to this project topic. The empirical review compares and adjusts their statements and findings with particular emphasis to this research topic. Adding to the structure and synthesis of existing related research, this research will revolve around the modeling of 5D BIM drivers for efficient construction project delivery in Nigeria.

Sami ur Rehman et al. (2020) in their work titled development of 5D model, energy efficiency and sustainability analysis using BIM with the objective of integration of construction processes of client requirements designs, construction and operation using tools of BIM, develop a 5D model of the construction which includes the 3D visualization, of the projects, the cost estimation, scheduling and simulation application of BIM focusing on the aspect of energy efficiency and sustainability and suggesting alternatives based on analysis of sustainability factors and energy consumption. They methodology adopted by them is the flow chat of literature review, project awarded, site selection, software learning, BIM model analysis and results. There major findings which include errors in drawings clash detection, simulation and energy analysis. Their major findings includes includes that there must be PC framework of high specifications for performing BIM operations, provision of council and approval of individuals that can get any sort of information and there should be correct information of BIM related instruments and programming projects before execution of work. With respect. To their research, no model was done and the method of data analysis is the qualitative type the only uses flow charts.

Lee, Tsong and Khamidi (2016), in their work, tilted 5D Building Information Modeling, A practicability review which focused on the subject that influences the practicability of 5D BIM, inclusive of modeling efforts, interoperability, information output and limitations, used the action research, which is the pilot study, with no collection of hard data, it used inputs like model drawings, schedule and time linear which were produced for examination. The action research pilot study outputs were followed by expert reviews. They further used a bungalow as a reference for the pilot study. The research methodology as to analyze and simulate the whole 5D BIM focused on modeling efforts, operability, information output and limitations with a hard on approach which they divided into 4 different stages. The first stage which involved the collection of inputs of building information into 3D model. The second stage comes in after the clients are satisfied with the initial design that comply to the specific requirements. The third stage will proceed within the clients are satisfied with the concluding 4D BIM, then lastly, the final stage involved visualization where the effort highly depends on existing 5D BIM quality. Qualitative observations were then summarized in a table from results obtained. To conclude the research, they stated that although more than 5 dimensions of information could possibly be incorporated in modeling, it was seen that excessive information may escalate the complexity and unfavorably for BIM implementation. It was further observed that there is significant level of practicability on all the 4 major stages of 5D BIM and the integration of information not only enhanced the efficiency and accuracy of projects in all stages, but also enables decision makers to have a sophisticated interpretation of information which is almost impossible with conventional 2D CAD workflow, observation also indicated that non-BIM capable stakeholders will have limitations to participate and benefit from 5D BIM modeling.

Muhammad et al. (2022) in their study titled Consortium Cost Estimation Optimization Using Building information Model (BIM), used several BIM- based estimation tools that were examined to assist different phases of design, including an assessment of correct estimation, they also examined software advantages and draw backs and finally reviewed BIM based estimating procedures and workflows. The methodology they adopted were BIM cost estimation using software like auto desk, revit auto desk and sigma estimates. This findings include that time saving as compared to traditional methods in auto desk revit is 10%, auto desk navisworks is 20% and sigma estimate is 30%. The accuracy of cost estimate is high, in auto desk naviswork medium and sigma estimate high. Difficulty level of operating software using autodesk revit is low, auto desk naviswork is high, and sigma estimate is medium. In difficulty level of operating software; in auto desk revit is low, in auto desk naviswork is high, and in sigma estimates is medium. Cost analysis and management is seen too low in auto desk revit, medium in auto desk navisworks and high in sigma estimate. For cost data bases, it's seen that auto desk revit not available, auto desk naviswork is not available but available in sigma estimates. The BOQ's in auto desk revit is short, those in auto desk naviswork is detailed and highly detached in sigma estimates. In view of this, the above authors use only software applications to optimize the use of 5D BIM in construction.

Stanley and Turnell (2015) in their study titled the benefits of and barriers to implementation of 5D BIM fir Quantity surveying in New Zealand with the aim of providing a snap shot of Auckland's QS's perceptions on the benefits of and barriers to the implementation of 5D BIM. This research methods which includes a cross sectional survey approach which was adopted over a small time frame. The purposive non probabilistic sampling was used by them to ensure that only those people that has some BIM experience were selected in addition to a well-structured questionnaire, a face to face interview was adopted by them, which gave the participants the opportunity to have wording of questions clarified. The findings with respect to 5D BIM benefits include positive response on regulation of projects, enhancement of collaboration on projects, early risk identification, and project conceptualization. While a neutral response on quality level of the finished product increase ability to print pout design detail, more efficient take off during budget, more efficient generation of quantities for cost, and lastly there were no negative responses in the benefit of drivers in construction industries. Looking at the barriers of 5D BIM implementation in their work, there is positive response on factors like lack of software compatibility, increase risk exposure which discourages companies, cultural resistance, lack of integration in the model, lack of protocol for coding objects and lastly, lack electronic standard for coding BIM. Neutral responses were observed in factors like increase risk exposure, in compatibility with current standard and less need for change were also recorded. Lastly negative responses with on in compatibility with industry recognize elements was recorded. This clearly shows that both the benefits and barriers of 5D BIM in construction industries as it relates to the drivers use in analyzing the benefits and barriers were identified.

Smith (2014) in his work titled BIM & the 5D project cost manager examined the global issue related to the role of project managers, cost management, professionals in the implementation and evolution of Building Information Modeling (BIM) in the construction industry. The methodology he used was the review of current industry trends and issues with BIM implementation and detailed interview with quantity surveying firms, he adopted three medium sized employers ranging between 10-20, and three large firms with 20 plus employers. The interview were conducted individually with experienced quantity surveying practitioners from each of the firms and involve general discussion on the benefits and issues surrounding BIM and automatic quantities implementation. The research found out that the quality of BIM models was a major concern, this is because BIM models require the input of vast amounts of inter connected data and information that is typically complex. Another findings were that all of the firms interviewed used automated quantities software to prepare quantities on their projects. Lack of standard software in compatibility along the project supply chain remains an issue despite great improvement in recent years. The full implementation of BIM on projects involves the sharing of information among project participants. Another finding was that the move toward changes of BIM capabilities and expertise require quantity surveying firms to reevaluate and reengineer their business practices. And lastly legal and contractual issues relating to BIM projects are still been at rest and creates considerable uncertainty for BIM participants.

Usman et al. (2019) in their work titled Benefits of Integrating5D BIM in cost management Practices in Quantity surveying firms which aim at assessing the benefits of integrating 5D BIM in cost management practices in quantity surveying firms employed the questionnaire survey which helped in gathering the opinion of respondents with knowledge of 5D BIM and the benefits of integrating 5D BIM in cost management practices. Their research work used the cronbach's alpha reliability value of responses which range from 0 to 1 and a value of 0.867 was obtained which is higher than the 0.7 value needed for further analysis. More so the kendall's coefficient of concordance (w) was used to check the level of agreement amongst correspondents. Base of their results of the kendall's test of concordance, significant grades of the data sets were investigated and obtained through significant level of analysis (SLA). The research found out that the risk of using 5D BIM are far out weighted by its benefits. It further found out that the benefits of integrating 5D BIM in cost management practices in quantity surveying firms which were surveyed and analyzed concluded that 5D BIM in cost management is a new trend in the construction industry. Young professionals responded more than other age groups and the major benefits of integrating 5D BIM will bring to the cost manager time saving and cost management practices, automated take off of quantities from drawings and improve visualization of projects during design and construction stages.

2.4 Research Gap

Some researchers have discussed the major barriers affecting the adoption of 5D BIM for efficient construction project delivery. Lee Tsong and Khamidi (2016) used the action research pilot study with no collection of hard data. The inputs like model drawings, schedule and time linear were produced for examination. In their research, a bungalow was used as a reference for the pilot study, and the study only focused on modeling efforts of 5D BIM, operability, information output and expert reviews. In this research work, the drivers of 5D BIM will be modeled for efficient construction project delivery, therefore the major research gap here is that the methodology used and the object of reference. The research did not further consult professionals to know and test their knowledge of 5D BIM and their implementations of 5D BIM drivers in the course of execution of projects. The research will seek to evaluate the extent of deployment of 5D BIM by professionals, identify the 5D BIM drivers and model them for easy and efficient construction project delivery.

Muhamed et al. (2022) in his research only focused on optimizing building information models relating it to cost estimation. In the research, they only focused on the software used in the optimization of different phases of design and costing. Furthermore, they only picked three BIM software which includes autodesk naviswork, revit autodesk and sigma estimation. They did not identify the target audience and did not define the methods used in data collection. Therefore this research will seek to fill the above mentioned gaps by identifying the target audience to the research and methods to be adopted in collecting data from respondents.

Stanley and Thurnell (2015) in their research work only focused on the benefits and barriers to implementing 5D BIM for quantity surveying. Though 5D BIM is directly related to digital costing, which is the sole professionalism of quantity surveyors, the research failed to identify if 5D BIM is widely accepted and used in the study area, how professionals in that area are conversant with 5D BIM and how often they adopt it before jumping to benefits and barriers of its implementation. This research will seek to fill the gap by evaluating the extent of deployment of the 5D BIM and will not limit the research to quantity surveyors, but will consult all professionals in the construction industries which includes; project managers, builders, architects and structural engineers.

Smith (2014) in his research, also focused on the global issues relating to the role of project managers and cost management professionals in the implementation and evolution of BIM in construction industry. His work only adopted the interview method of data collection, focused on quantity surveying firms alone. This research will seek to fill the gap by modeling the drivers used for efficient construction project delivery using both questionnaire and interview as tools for data collection.

In this study, 5D BIM adoption is expected to provide efficient construction project delivery in Nigerian construction industries through the evaluation of the extent of 5D BIM deployment and identifying the drivers of 5D BIM in construction project delivery.

Therefore, in this study, the adoption of 5D BIM will assist Nigerian construction industries in the visualization of different stages of the construction project, improve the effectiveness of project delivery and improve workforce performance in the construction industry.

A major research Gap exists with respect to this research topic is the fact that to the best of my knowledge no much research work was conducted with regards to this aspect in Nasarawa state. It will also help in adequate documentation of construction project for both private and government agencies.

CHAPTER THREE

METHODOLOGY

3.1 Research Design

Non experimental design is the type of design that uses at least two independent variables. Based on the criterion of amount of control, the design is categorized as non-experimental (also referred to as per-experimental). Non experimental studies allow the least amount of control because they deal with phenomena occurring in the natural environment. (Mildner, 2019).

This research is a mixed method research. The mixed method research is a research that combines both qualitative and quantitative methods. This could include using both questionnaire and interview to collect data.

The research will focused on modeling 5D BIM drivers for efficient construction project delivery. It will also identify those drivers and measure the extent of their deployment in Nigerian construction industries.

3.2 Population of the Study

Satishprakash Shukla (2020), stated that population refers to the set or group of all the units on which findings of the research are to be applied.

With regard to this study, the total population of this research encompassed two target audience i.e, the construction companies already identified, and all the professionals working in those construction companies, engineers, project managers, builders, architects, quantity surveyors and so on.

On one hand, five (5) construction companies currently executing major projects within Nasarawa state will be contacted for the purpose of this research, and on the other hand, the total numbers of registered professionals within Nasarawa state as identified by the ministry of works and some professional bodies as seen below;

Registered Professionals	Total numbers
Architects	19
Builders	14
Quantity surveyors	9
Project managers	3
Engineers (civil, electrical & mechanical)	26
Total number	71

3.3 Sampling

3.3.1 Sample Frame

This consists of the total number of the target audience. A sample frame is the set of source materials from which the sample is selected. The definition also encompasses the purpose of sampling frame which is to provide the means for choosing the particular members of the target population that are to be consulted in the survey (Anthony, 2003).

3.3.2 Sample Size

Simarjeet Kaur (2017) stated that, sample size determination is the essential step in research methodology. It is an act of choosing the number of observers or replicates to include in statistical sample. In some situations, increase in precision for larger sample size is minimal or even nonexistent. Sample sizes are judged based on the quality of resulting estimates.

For the purpose of this research, the census sampling method was adopted. This is because the major challenges faced by professional bodies in construction industries in Nasarawa state is that, most professionals from Nasarawa state tend to register with their bodies in Abuja and hence the low number of professionals for the purpose of this study.

United States Census Bureau (n.d) stated that, census sampling refers to the process of selecting a sample from a larger population for data collection purposes. In this method, data is collected from every member of the population or a subset of the population.

3.3.3 Sampling Technique

The sampling technique used for the purpose of this research is the Purposive sampling. Purposive sampling is a non-probability sampling method that involves selecting cases based on the specific purpose and reason of study (Patton 2015). Also, the research is both a quantitative and qualitative research because it focuses on how 5D BIM is deployed in construction project delivery and it identifies the drivers of 5D BIM in construction delivery. Quantitative research is systematic empirical investigation that uses statistical, mathematical, or computational techniques to collect and analyze numerical data, aiming to identify patterns, relationships, and trends in a population or sample. It involves the measurement of variables and the application of statistical methods to analyze and interpret the data (Creswell, 2014).

3.4 Methods of Data Collection

Jones (2017) stated that data collection in research refers to the systematic process of gathering assessing and documenting relevant information or facts in order to answer research questions or test hypotheses. The process involves using various methodologies and tools to collect data from primary and or secondary sources, which surveys, interviews, experiments, observation, or existing records. Theses collected data points are then organized, analyzed, and interpreted to draw conclusions and make informed decisions in research endeavors. The methods used in data collection for the purpose of this research are the primary and secondary sources.

3.4.1 Primary Sources

The U.S National Park Service (n.d.) stated that, a primary source of data collection refers to the original, firsthand or direct evidence that is used for research or analysis. It involves gathering data directly from the source of the information without any intermediaries or interpretations primary sources are the most reliable and authentic sources of data as they provide first hand information and are unfiltered by other individuals or sources. Questionnaires were distributed to the population of the study area and personal observations survey was made where pictures of the construction projects were taken.

3.4.1.1 Questionnaire

A questionnaire is a primary instrument consisting of a series of a series of questions or prompts that are used to gather information from individuals or groups for the purpose of data collection and analysis (Babbie, 2016). The questionnaire that was used for the purpose of this research is the closed/structured questionnaire. The closed/structured questionnaire was administered to the construction companies and professionals working in these construction companies.

3.4.1.2 Interview

A research interview is a qualitative data collection method in which a researcher conducts a one on one conversation with a participant to gather in-depth information on a specific topic or research question (Creswell 2014). The type of interview used for the purpose of this research is the semi-structured interview, where list of questions were asked at the same time allowing for flexible and open ended response.

3.4.2 Secondary Sources

Smith (2018) stated that, secondary source of data collection is a research study that analyses data from previously published articles or books. The researcher does not collect the data firsthand but uses existing data that has already been collected by other researchers. Journals, articles, textbooks, and online published literatures were used for this study.

3.5 Instrumentation

The two major instruments used in collection of data in this thesis are the questionnaire and interview, then physical inspections also known as the reconnaissance survey. A total number of seventy one (71) questionnaires were administered, and five (5) construction companies were interviewed.

3.6 Methods of Data Presentation and Analysis

After collection of the data obtained by the use of the instruments above, the data from objectives one was presented and analyzed using descriptive statistical tables and charts. The data from objectives two were analyzed using factor analysis to identify the drivers. . Factor analysis as stated by Kempf-Leonard (2005) is a data reduction technique that allows researchers to summarize data and express relationship among a large number of variables more succinctly. It also helps to identify the underlying dimensions that are not directly observed but can best explain the relationship among the measured variables. Pictures obtained from the physical inspection were also presented. The data from objectives three were modeled using DEMATEL which simply means decision making trial and evaluation laboratory analysis which helps make decision when there are multiple alternatives and multiple criteria to consider.

3.6.1 Factor Analysis

The twenty two identified drivers of 5D BIM was subjected to principal component analysis using IBM SPSS statistics version 25.0. The coefficient was inspected to check whether they have value of 0.5 and above to see if it will be acceptable for consistency and reliability measures. All factors with value of below 0.5 were eliminated. Series of factor analysis formula is seen below;

Factor extraction for eigen value: (should be > 1)

If the number of factors are not sufficient or convinced, the no. of factors could be fixed by the formula. The formula is $^2r = \frac{2n+1-\sqrt{8n}+1}{2}$ - - - - (i)

Where r= number of factors n= number of variables

KMO measures	Interpretations
KMO≥ 0.90	Marvelous
0.80≤kmo<0.90	Meritorious
0.70≤kmo<0.80	Average
0.60≤kmo<0.70	Mediocre
0.50≤kmo<0.60	Terrible
Kmo<0.50	Unacceptable

Source Google 2023

Communalities

For h^2 (j) denote jth largest communalities among the p variables

Then for $1 \leq j \leq p$

$h^2 (j) \geq 1\text{-}Pp+1\text{-}j(\sum)$ - - - - - - - (ii) where Pp+1-j(∑) is the (p+i-j)th largest eigen value of ∑

3.6.2 DEMATEL Analysis

The DEMATEL analysis as related to objective three, which is to model the drivers of 5D BIM will be used to identify the most effective drivers to be adopted for efficient construction project delivery. It will visualize the structure of complicated causal relationship through matrix or diagraphs. It is a kind of structural modeling approach which will be useful in analyzing the cause and effect relationship among factors and aid in the development of map to reflect relative relationship within them and can be used for investigation and solving complicated problems.

For direct relationship (average) matrix A

N factors=H

$X, X^2 \ldots X^H$ - - - - - - (i)

Non negative matrixX^K= [xij^k]n×n

Within 1< k < H

= [aij] n×n

$= \frac{1}{H} \sum_{K=1}^{H} [xij] n \times n$ - - - - - (ii)

Determine the normalized initial direct relationship matrix

$D = \frac{A}{s}$

Total relationship matrix

$\lim_{n\to\infty} D^{n=[0]n} \times n$ - - - - - (iii)

[0]n×n is an n

Xn null matrix

Sum of rows and columns

[ri] n×1 = ($\sum_{j=1}^{n} tij$)n×n - - - - (iv)

[ci] 1×n = ($\sum_{i=1}^{n} tij$)n×n - - - - (v)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

In this chapter, the study firstly presents the results of the survey in the form descriptive statistics using tables, figures and charts as well as other statistic tools to arrive at the findings in the first instance. Secondly, the responses from the focused and targeted respondents on the subject matter are based on extent of deployment of 5D BIM on construction project delivery in Nasarawa state, the identification of the drivers of 5D BIM on construction project delivery and lastly modeling the 5D BIM drivers using DEMATEL analysis. Out of 71 questionnaires allocated to the target respondents, only 62 were returned as follows:

Table 4.1: Questionnaire distribution and responses

RESPONDENTS	DISTRIBUTION	RESPONSES	(%)RESPONSES
Project Managers	3	3	100
Builders	14	11	78.6
Architects	19	16	84.2
Structural engineers	26	25	96.1
Quantity Surveyor	9	7	77.7
Total	71	62	87.3

Source: Field Data 2023.

From table 1 above, a total of seventy one (71) questionnaires were sent out to respondents; however a total of sixty two (62) were returned. This represents the targeted sample for this research.

4.1.1 Demographic Information of Respondents

Below are figures of the demographic information of the respondents of the questionnaire.

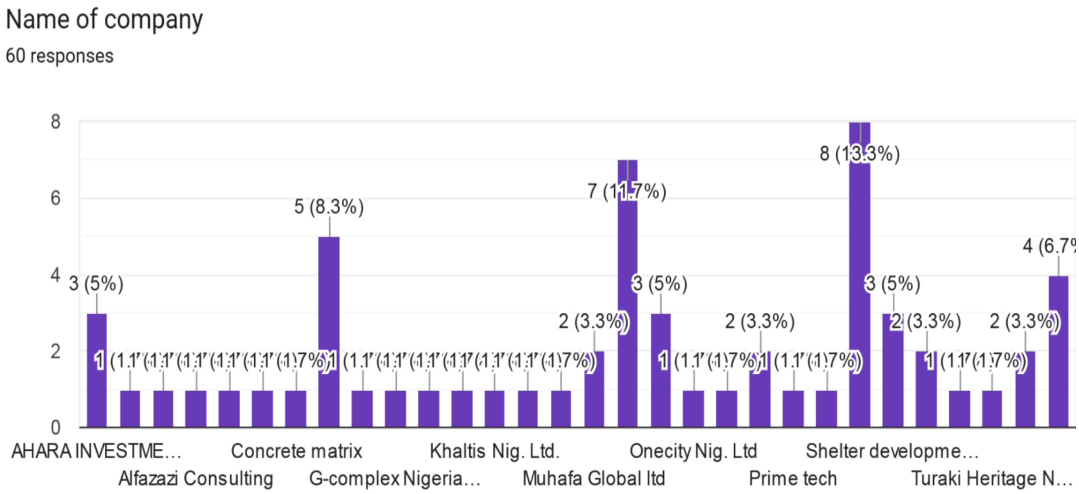


Figure 4.1 Name of company

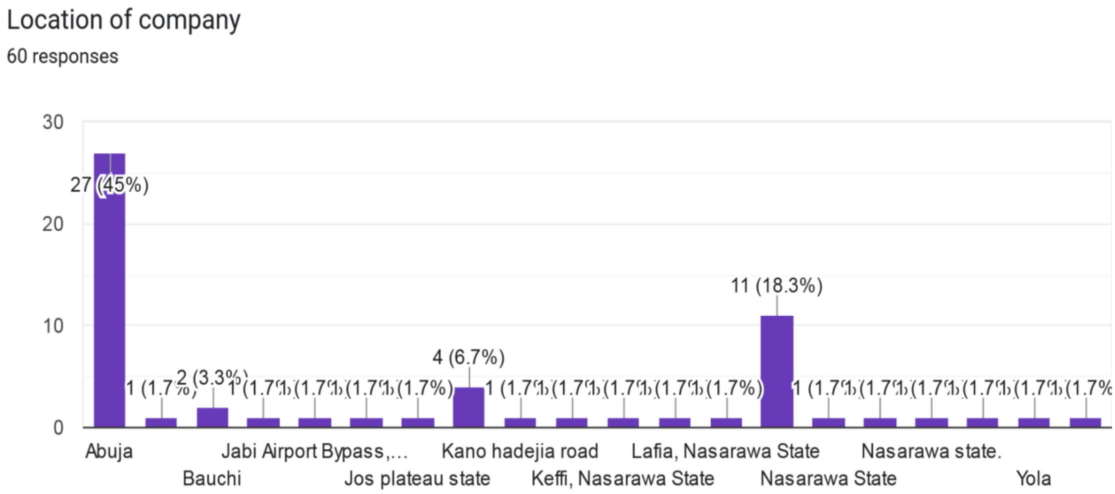


Figure 4.2 Location of company

Figure 4.2 represents the location of the companies consulted, Abuja has the highest rank because most of the companies operating and currently executing projects in Nasarawa state are based In Abuja, then the indigenous companies of Nasarawa state followed by Kano State.

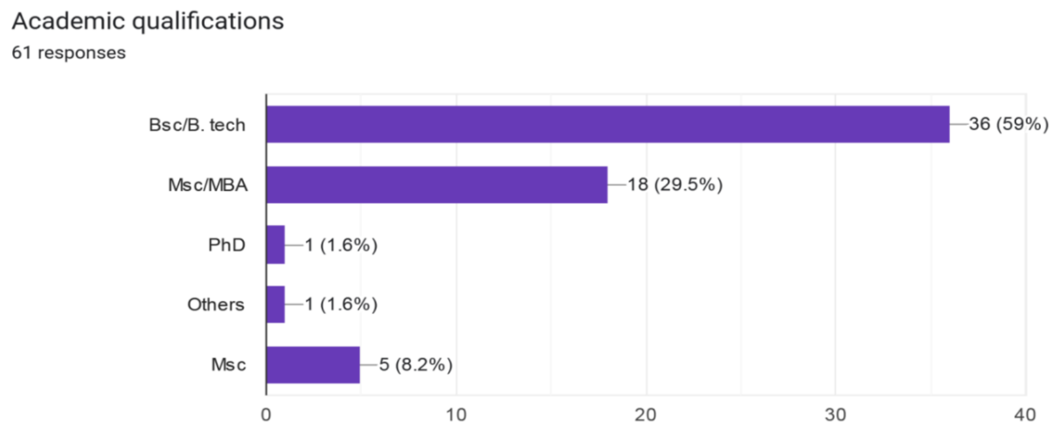


Figure 4.3 Academic Qualification

The figure above shows the academic qualifications of the respondents from various construction companies. The figure above shows that 59% of the respondents have a qualification of either Bsc or B. tech, followed by MSc and MBA with total response of 37.7%. This clearly shows that majority of the respondents are Bsc or B.Tech holders therefore making it possible that most of the professionals have heard about 5D BIM but are not too knowledgeable about it. This further explains that professionals with Msc or MBA degrees and PhD are more knowledgeable and conversant with 5D BIM but their presence in construction industries are very minimal.

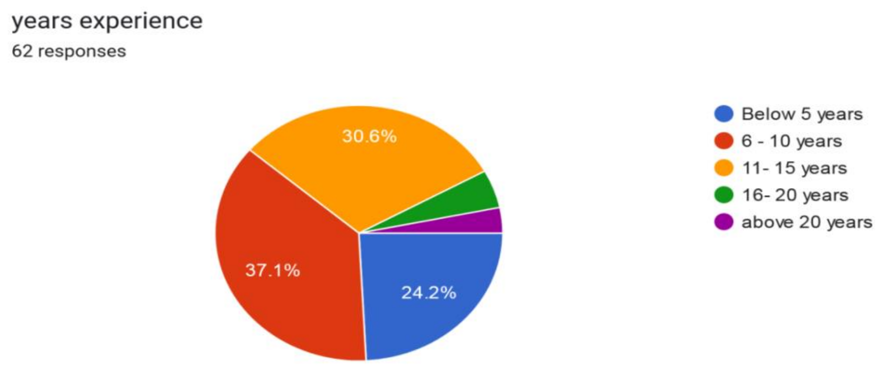


Figure 4.4 Years of Experience

The figure above shows that 37.1% of the respondents have an experience of 6-10 years, followed by 30.6% of respondents are have experience of between 11-15 years and then respondents with below 5years have 24.2%.

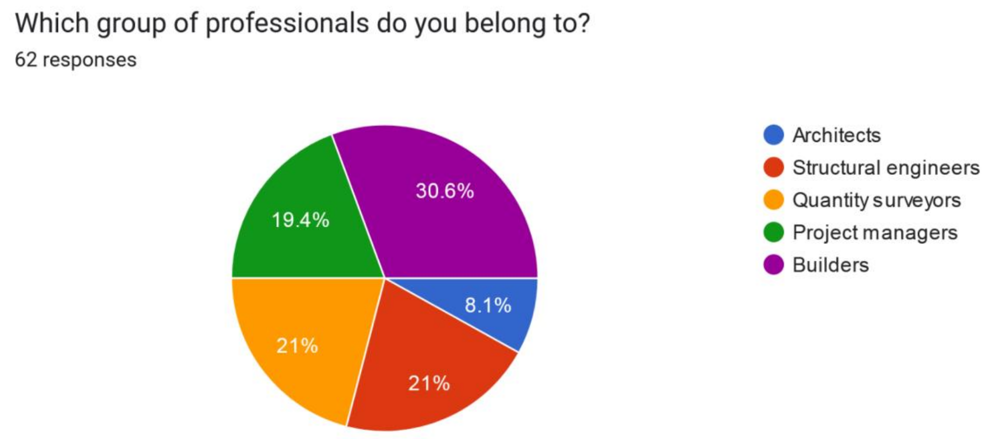


Figure 4.5 Group of professionals you belong to

The figure above shows the response of professionals. Builders have the highest response with 30.6%, followed by structural engineers and quantity surveyors each with 21%, 19.4 are projects managers and lastly 8.1% architects.

4.1.2 Extent of Deployment of 5D BIM on Construction Project Delivery in Nasarawa State

The Extent of Deployment of 5D BIM on construction projects delivery in Nasarawa state is seen in the responses of professionals from different construction companies in the figures below;

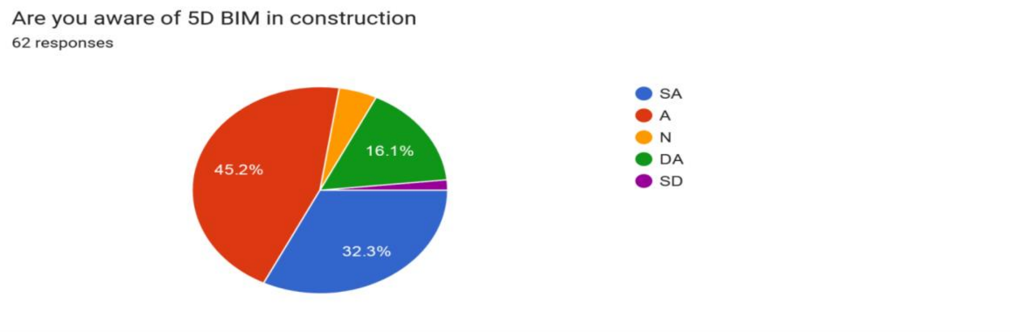


Figure 4.6 Are You Aware of 5D BIM in construction

In the above figure, 45.2% of the respondents agree that they are aware of 5D BIM in construction, and 32.3% strongly agreed that they are aware, while only 16.1% disagreed that they are aware of 5D BIM in construction

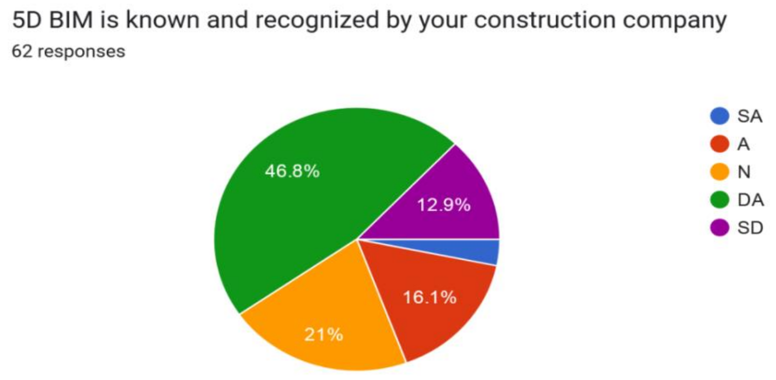


Figure 4.7 5D BIM is known and Recognized by your construction company

The figure above shows that 46.8 % of the respondents disagree that 5D BIM is recognized by their construction company, and 12.9 strongly disagreed about the recognition of 5D BIM by their construction company while 21% of the respondents chose to be neutral which signifies that they aren't aware whether their construction companies recognize it or not and lastly 16.1% of respondents agreed that their construction companies recognize 5D BIM in the execution of construction projects

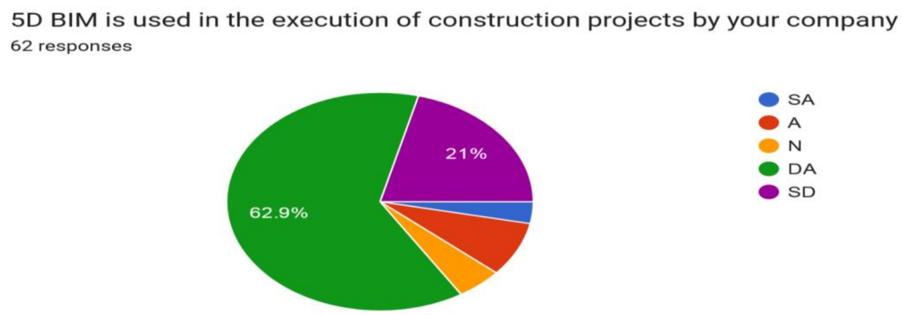


Figure 4.8 5D BIM is used in the Execution of Construction Projects by your Company

The above figure shows that 62.9% and 21% of the respondents disagreed and strongly disagreed that 5D BIM is used in the execution of projects. Therefore this signifies that the totality of the respondents disagreed that 5D BIM is used in the execution of construction projects by their various companies.

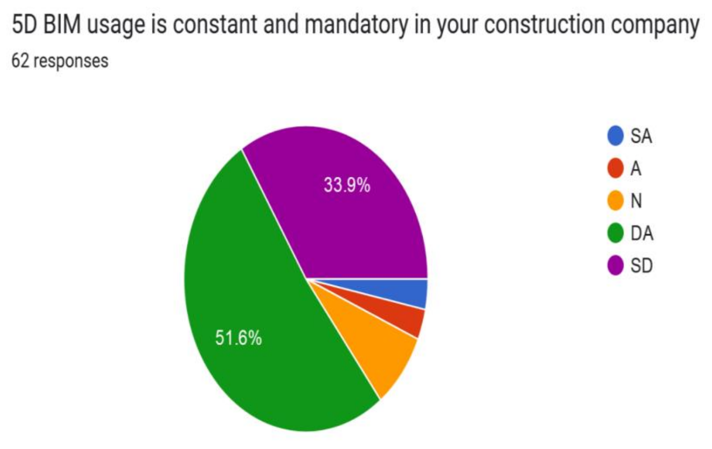


Figure 4.9 5D BIM usage is Constant and Mandatory in your construction company

The above figure shows that 51% and 33.9% of the respondents disagree and strongly disagreed that 5D BIM usage is constant and mandatory in the execution of construction projects by their companies.

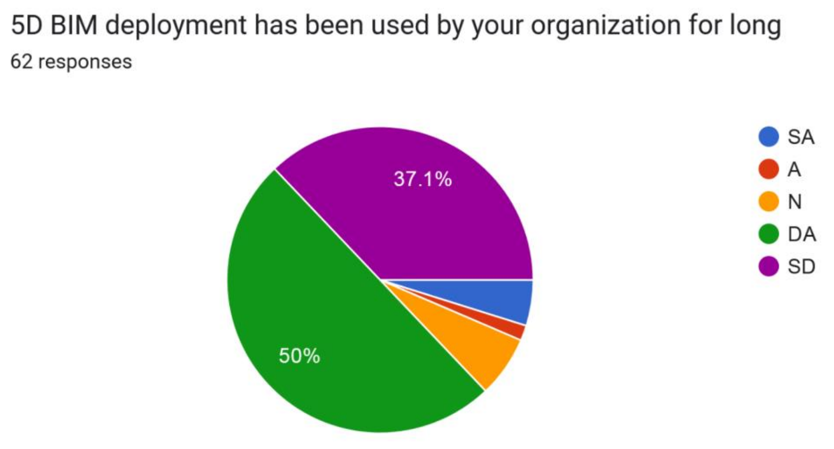


Figure 4.10 5D BIM Deployment has been used by your Organization for long

The figure above also shows that 50% of the respondents disagreed that 5D BIM deployment has been used by their construction companies whereas 37.1%of the respondent strongly disagreed that 5D BIM has been used by their organization for a long period of time. This clearly indicates that the construction companies consulted have not used 5D BIM in the execution of construction projects.

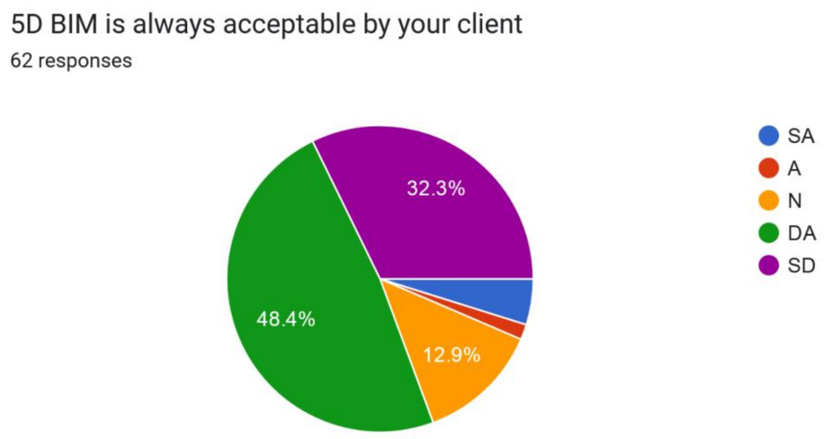


Figure 4.11 5D BIM is always acceptable by clients

The figure above shows that 48.4 % of the respondents disagreed that 5D BIM usage is acceptable by their clients, where as 32.3 % strongly disagreed that their clients accept the use of 5D BIM in the execution of their projects, while 12.9% of the respondents chose to stay neutral on whether their clients accept the usage of 5D BIM or not.

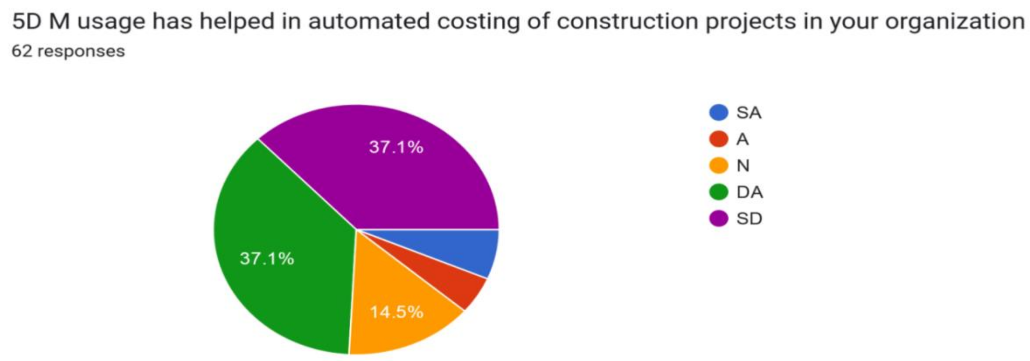


Figure 4.12 5D BIM usage has helped in automated costing of construction projects

The figure above shows that 37.1% of the responses disagreed and strongly disagreed that the usage of 5D BIM helps in automated costing of construction projects, while 14.5% of the respondents are neutral meaning they are not sure if 5D BIM helps in automated costing of construction projects or not.

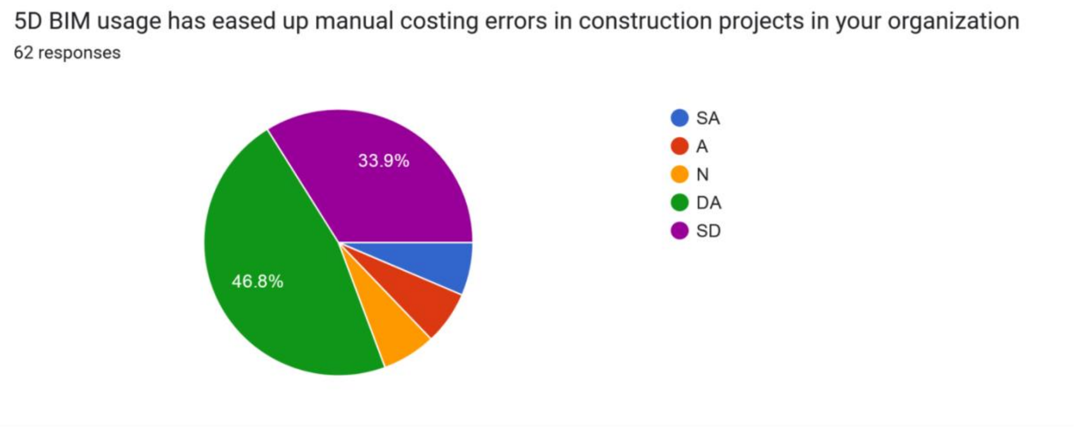


Figure 4.13 5D BIM usage has eased up Manual Costing errors in construction

The figure above indicates that 46.8% of the respondents disagreed that the usage of 5D BIM has eased up manual costing errors in construction projects, while 33.9% of strongly disagreed that 5D BIM usage has eased up manual costing errors in construction. This shows that majority of the respondents have disagreed that 5D BIM usage has eased up manual costing errors in construction projects.

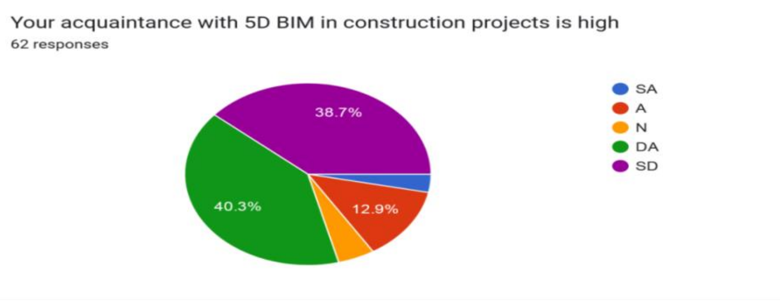


Figure 4.14 Your Acquaintance with 5D BIM in Construction Projects is High

The figure above shows that 40.3% of the respondents disagree that they are acquainted with 5d BIM in construction, while 38.7% strongly disagreed that they are acquainted with 5D BIM in construction and only 12..9% has agreed that they are acquainted with 5D BIM in construction projects. This clearly shows that only a small percent of the respondents are aware and acquainted with 5D BIM usage while the majority are either not aware or acquainted of its usage in construction.

4.1.3 Identification of the Drivers of 5D BIM on Construction Project Delivery in Nasarawa state

In this section, factor analysis was used to identify the drivers of 5D BIM on Construction project delivery. The KMO and Bartlett's test the sphericity of the approximate Chi-square, difference and significance of the drivers.

Table 4.2 KMO and Bartlett's Tests of the Drivers of 5D BIM

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.613
Bartlett's Test of Sphericity	Approx. Chi-Square	5447.829
	Df	231
	Sig.	.000

Twenty-two (22) items of the drivers of 5D BIM on construction project delivery were subjected to principal component analysis using IBM SPSS Statistics version 25.0. Before this, the suitability of data for analysis was assessed. Inspection of the correlation matrix showed many of the coefficients had values of 0.5 and above. The Kaiser-Meyer- Olkin (KMO) measure of sampling adequacy of 0.613 was obtained. This value is within the desirable value of 0.6. From the table above, Bartlett's test of sphericity was 5447.829 with an associated significance of 0.000. Also, a Cronbach's alpha of 0.865 was realized, suggesting an acceptable level of internal consistency and reliability in the measures and the scale.

Table 4.3 Communalities of the drivers of 5D BIM on construction project delivery in Nasarawa state.

Communalities		
	Initial	Extraction
Visualization is enhanced	1.000	.664
Accurate quantity takeoff	1.000	.649
Efficient schedule planning	1.000	.538
Enhanced project coordination	1.000	.619
Improved cost estimation	1.000	.628
Management of risk	1.000	.591
Adoption of technology and innovation	1.000	.553
Project Management collaboration	1.000	.514
Procurement and supply management	1.000	.500
Planning and design	1.000	.619
Real time monitoring	1.000	.802
Enhanced Communication	1.000	.869
Resource allocation	1.000	.875
Change Management	1.000	.848
Heightened cost forecasting	1.000	.856
Shorter project life cycle	1.000	.546
Multi-platform Access	1.000	.562
Early involvement of contractors	1.000	.593
The Clash detection and clash avoidance	1.000	.584
Construction schedule optimization	1.000	.546
Clear project objectives and scope definition	1.000	.571
Availability of accurate and updated project information	1.000	.633
Extraction Method: Principal Component Analysis.		

From the table above, the average communality of the variables after extraction was 0.644. Hence, the communalities extracted support the use of factor analysis on the variables. It can be observed that no item had extracted eigenvalues less than the 0.50 cut-off point, hence all the variables are qualified for further analysis.

Table 4.4 Total Variance Explained of 5D BIM Drivers

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.413	15.512	15.512	3.413	15.512	15.512	2.118	9.625	9.625
2	2.160	9.816	25.328	2.160	9.816	25.328	1.939	8.813	18.438
3	1.970	8.955	34.284	1.970	8.955	34.284	1.921	8.734	27.171
4	1.565	7.112	41.396	1.565	7.112	41.396	1.861	8.461	35.632
5	1.338	6.080	47.475	1.338	6.080	47.475	1.764	8.016	43.648
6	1.140	5.183	52.658	1.140	5.183	52.658	1.408	6.399	50.047
7	1.043	4.741	57.400	1.043	4.741	57.400	1.361	6.185	56.232
8	1.011	4.596	61.996	1.011	4.596	61.996	1.268	5.764	61.996
9	.973	4.423	66.419						
10	.888	4.036	70.455						
11	.838	3.811	74.267						
12	.784	3.564	77.831						
13	.750	3.408	81.239						
14	.702	3.190	84.428						
15	.622	2.828	87.257						
16	.600	2.726	89.983						
17	.537	2.439	92.422						
18	.530	2.408	94.830						
19	.414	1.881	96.711						
20	.331	1.505	98.216						
21	.260	1.183	99.398						
22	.132	.602	100.000						
Extraction Method: Principal Component Analysis.									

From the result presented in table above, an eight-factor component solution which explained a total of 61.996% of the variance was obtained. The first component explained 15.512% of the variance; the second component explained 9.816%; while the third component 8.955%; while the eight and last component was 4.596%. The total variance explained is above the recommended minimum of 50%. The eight components were named according to the factor with the highest loading in the cluster. These are explained in greater details in the discussion section. Also, the screen plot for the factor analysis is shown in figure 4.15.

Figure 4.15 shows the scree plot derived from the EFA conducted. The report retains seven factors based on Kaiser's rule which recommends maintaining elements with eigenvalues greater than unity and the fact that the scree plot showed a sharp curve after the seventh factor. The seven factors account for over 50% of the total variance explained.

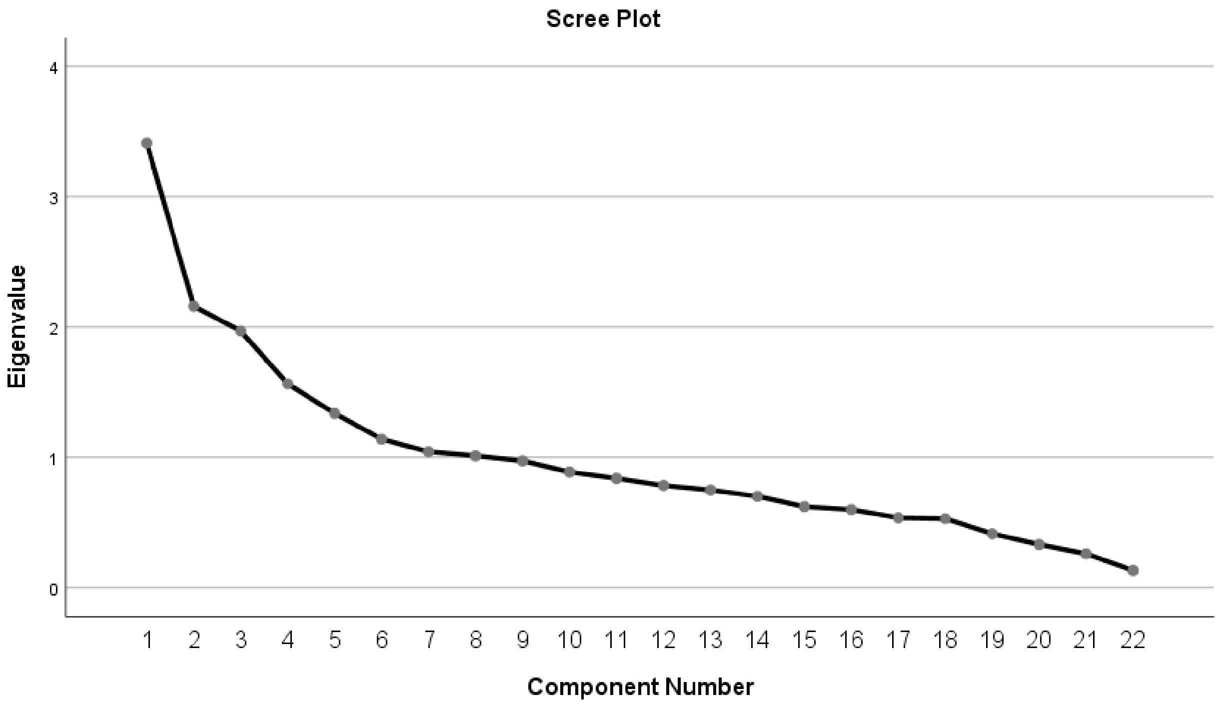


Figure 4.15 Scree Plot of 5D BIM Drivers

Table 4.5 Component Matrix

Component Matrix[a]								
	Component							
	1	2	3	4	5	6	7	8
Visualization is enhanced	.794							
Accurate quantity takeoff	.732							
Efficient schedule planning	.625							
Enhanced project coordination	.666							
Improved cost estimation		.911						
Management of risk		.909						
Adoption of technology and innovation			.653					
Project Management collaboration			.552					
Procurement and supply management				.921				
Planning and design				.913				
Real time monitoring					.746			
Enhanced Communication					.708			
Resource allocation					.630			
Change Management						9		
Heightened cost forecasting						1		
Shorter project life cycle							.743	
Multi-platform Access							.542	
Early involvement of contractors								
The Clash detection and clash avoidance								
Construction schedule optimization								
Clear project objectives and scope definition								
Availability of accurate and updated project information								
Extraction Method: Principal Component Analysis.								
a. 8 components extracted.								

The findings from the results shown above indicate that 22-factors can be grouped into eight decision matrix (components) for 5D BIM drivers for construction project delivery. However, 8-principal components were later extracted for effectiveness. In the first component, 4 factors in that order loads positively maximally, 2 factors, loads positively maximally in the second component, while 2 factors load positively maximally in the third component. In the fourth component, 2 factors load positively maximally. While in the fifth, sixth, seventh and eight components, 3, 2, 2, 5 factors respectively load positively maximally. From this result, the components that emerged could be the dominant underlining drivers of 5D BIM in construction project delivery.

4.1.4 Modeling of 5D BIM drivers Using DEMATEL Analysis.

In this section, the drivers identified from the above factor analysis were then categorized into eight categories, and only a small sample of twenty responses was chosen in this section. Decision making trial and evaluation laboratory (DEMATEL) technique is used in the visualization of the structure of complicated casual relationships through matrixes or diagraphs. It is a kind of structural modeling approach which is especially useful in analyzing the cause and effect relationship among factors and aid in the development of a map to reflect relative relationship within them and can be used for investigation and solving complicated and inter turned problems. DEMATEL is also used for better decision making under different environments since many real world systems include imprecise and uncertain information (Li si et, al 2018)

Table 4.6 Modeling 5D BIM Drivers using DAMATEL Analysis

Rating /Linguistic Scale Values

Variable	Influence score
No influence	0
Very low influence	1
Low influence	2
High influence	3
Very high influence	4

Using the five level scales containing the following scale item factor influence relationships and linguistic assessment of the evaluators' opinion was carried out viz: Very low, Low, Medium, High, and Very high (see Table 4.2).

Table 4.7 Eight Classified drivers

S/N	5D BIM drivers in Construction Projects	Code
1	Procurement and supply management	Ps
2	Real time monitoring	Rm
3	Visualization is enhanced	Vi
4	Adoption of technology and innovation	At
5	Change Management	Cm
6	Shorter project life cycle	Sp
7	Early involvement of contractors	Ei
8	Improved cost estimation	Ic

The above eight drivers were classified by the above factor analysis from objective two. A sample of only twenty respondents was used out of the sixty two already responded questionnaires.

Table 4.8: Linguistic assessment of the evaluators' opinion (average) of Drivers of 5D-BIM

	Ps	**Rm**	**Vi**	**At**	**Cm**	**Sp**	**Ei**	**Ic**
Ps	H	VH	NO	L	NO	H	VH	H
Rm	L	VL	VH	H	H	H	NO	H
Vi	NO	NO	H	NO	VH	VH	NO	NO
At	NO	NO	L	L	NO	H	H	L
Cm	L	L	NO	VL	L	L	L	VL
Sp	VL	H	VH	NO	H	VL	VH	H
Ei	NO	H	H	NO	NO	L	H	L
Ic	NO	H	VH	NO	L	NO	L	NO

From the above table, the diagonal plot indicates that the influence of the above mentioned drivers signifies high influence on PS, very low influence for RM, then High influence on VI, low influence on AT, low influence on CM, very low influence on SP, High influence on EI, and lastly no influence on IC.

Table 4.9: Conversion of the Linguistic assessment to numbers of Drivers of 5D-BIM

	Ps	**Rm**	**Vi**	**At**	**Cm**	**Sp**	**Ei**	**Ic**
Ps	0.75	0.917	0.083	0.5	0.083	0.75	0.917	0.75
Rm	0.5	0.25	0.917	0.75	0.75	0.75	0.083	0.75
Vi	0.083	0.083	0.75	0.083	0.917	0.917	0.083	0.083
At	0.083	0.083	0.5	0.5	0.083	0.75	0.75	0.5
Cm	0.5	0.5	0.083	0.25	0.5	0.5	0.5	0.25
Sp	0.25	0.75	0.917	0.083	0.75	0.25	0.917	0.75
Ei	0.083	0.75	0.75	0.083	0.083	0.5	0.75	0.5
Ic	0.083	0.75	0.917	0.083	0.5	0.083	0.5	0.083

From the above table, the linguistic assessment is converted to numbers which is seen as follows, 0.75 on PS signifying high influence, 0.2 on RM signifying low influence, 0.75 on VI signifying high influence, and 0.5 on AT signifying low influence, hen 0.5 on CM also signifying low, and very low influence on SP with 0.25, 0.75 influence on EI signifying high influence and lastly 0.083 which is below 0.1 signifying no influence.

The conversion of the Evaluated DEMATEL linguistic assessment numbers (table 4.6.3) is done based on the Equation stated in the method of data analysis.

Table 4.10: Initial Influence (direct relation) Matrix for Drivers of 5D-BIM

	Ps	Rm	Vi	At	Cm	Sp	Ei	Ic
Ps	0.157895	0.193053	0.017474	0.105263	0.017474	0.157895	0.193053	0.157895
Rm	0.105263	0.052632	0.193053	0.157895	0.157895	0.157895	0.017474	0.157895
Vi	0.017474	0.017474	0.157895	0.017474	0.193053	0.193053	0.017474	0.017474
At	0.017474	0.017474	0.105263	0.105263	0.017474	0.157895	0.157895	0.105263
Cm	0.105263	0.105263	0.017474	0.052632	0.105263	0.105263	0.105263	0.052632
Sp	0.052632	0.157895	0.193053	0.017474	0.157895	0.052632	0.193053	0.157895
Ei	0.017474	0.157895	0.157895	0.017474	0.017474	0.105263	0.157895	0.105263
Ic	0.017474	0.157895	0.193053	0.017474	0.105263	0.017474	0.105263	0.017474

The initial influence (direct relation-relation) matrix (table 4.5) is calculated based on the Equation stated in the method of data analysis. Construction of the initial direct relation matrix). The initial relation matrix A is an *x n x* matrix can be obtained through pairwise comparison in which *Aij* is denoted as the degree to which the criterion i affects the criterion j, i.e. *A=[Aij]*.

Table 4.11: Normalized Direct-influence for Drivers of 5D-BIM

	Ps	Rm	Vi	At	Cm	Sp	Ei	Ic
Ps	0.404033	0.596304	0.538704	0.414919	0.442083	0.585418	0.632691	0.538496
Rm	0.440101	0.621275	0.741914	0.510374	0.601365	0.666499	0.637898	0.620959
Vi	1.327738	0.499965	0.623124	0.360363	0.536817	0.607801	0.53046	0.451666
At	0.353599	1.543026	0.636544	0.449271	0.471661	0.626494	0.671262	0.547654
Cm	0.395117	0.578245	1.560484	0.402129	0.506095	0.578837	0.617515	0.498105
Sp	0.352349	0.591784	0.648686	1.369381	0.526824	0.531638	0.659498	0.552706
Ei	0.339253	0.607494	0.634641	0.379682	1.444503	0.573005	0.647386	0.528612
Ic	0.34803	0.611209	0.675212	0.393912	0.510451	1.527303	0.618908	0.488896

The normalized direct relation matrix D (Normalize the direct relation matrix) was calculated by using the formula (1), in which all elements of the matrix D are between all elements on the principal diagonal elements as shown in table 4.6.

Table 4.12: Total Relations Matrix for Drivers of 5D-BIM

	Ps	Rm	Vi	At	Cm	Sp	Ei	Ic
Ps	0.596304	0.538704	0.414919	0.442083	0.585418	0.632691	0.538496	0.300261
Rm	0.621275	0.741914	0.510374	0.601365	0.666499	0.637898	0.620959	0.409059
Vi	0.499965	0.623124	0.360363	0.536817	0.607801	0.53046	0.451666	0.32369
At	0.543026	0.636544	0.449271	0.471661	0.626494	0.671262	0.547654	0.426418
Cm	0.578245	0.560484	0.402129	0.506095	0.578837	0.617515	0.498105	0.396516
Sp	0.591784	0.648686	0.369381	0.526824	0.531638	0.659498	0.552706	0.309846
Ei	0.607494	0.634641	0.379682	0.444503	0.573005	0.647386	0.528612	0.366546
Ic	0.611209	0.675212	0.393912	0.510451	0.527303	0.618908	0.488896	0.345683

The total relation matrix T (Building total relation matrix) is calculated by using formula as depicted in method of data analysis.

Table 4.13: The Sum of Influences on Drivers of 5D-BIM

5D BIM Drivers	Ri	Ci	Ri + Ci	Ri-Ci	Cause/Effect
Ps	4.048876	4.6493	8.698176	-0.60042	Effect
Rm	4.809343	5.0593	9.868643	-0.24996	Effect
Vi	3.933886	3.28	7.213886	0.653886	**Cause**
At	4.37233	4.0398	8.41213	0.33253	**Cause**
Cm	4.137926	4.697	8.834926	-0.55907	Effect
Sp	4.190363	5.0156	9.205963	-0.82524	Effect
Ei	4.181869	4.2271	8.408969	-0.04523	Effect
Ic	4.171574	2.878	7.049574	1.293574	**Cause**

Furthermore, the sum of rows and sum of columns of matrix T (total relations Matrix) was achieved through the formulas (3) and (4) in chapter three, in which R denote the sum of rows and C denote the sum of columns. By using equations in the method of data analysis, the causal relationship diagram can be acquired. At this stage, if the value of R - C is positive, it means that the criteria (5D BIM Drivers) has more impact on other criteria. Finally, the complete procedure of the proposed method is shown in figure 1. The cause–effect diagram was drawn after obtaining horizontal axis (Ri + Ci) and vertical axis (Ri - Ci). While (Ri + Ci) refers to the strength of influence among (5D BIM Drivers) criteria, (Ri - Ci) refers to the influence relation among criteria. The cause–effect diagram is shown in figure 1 below.

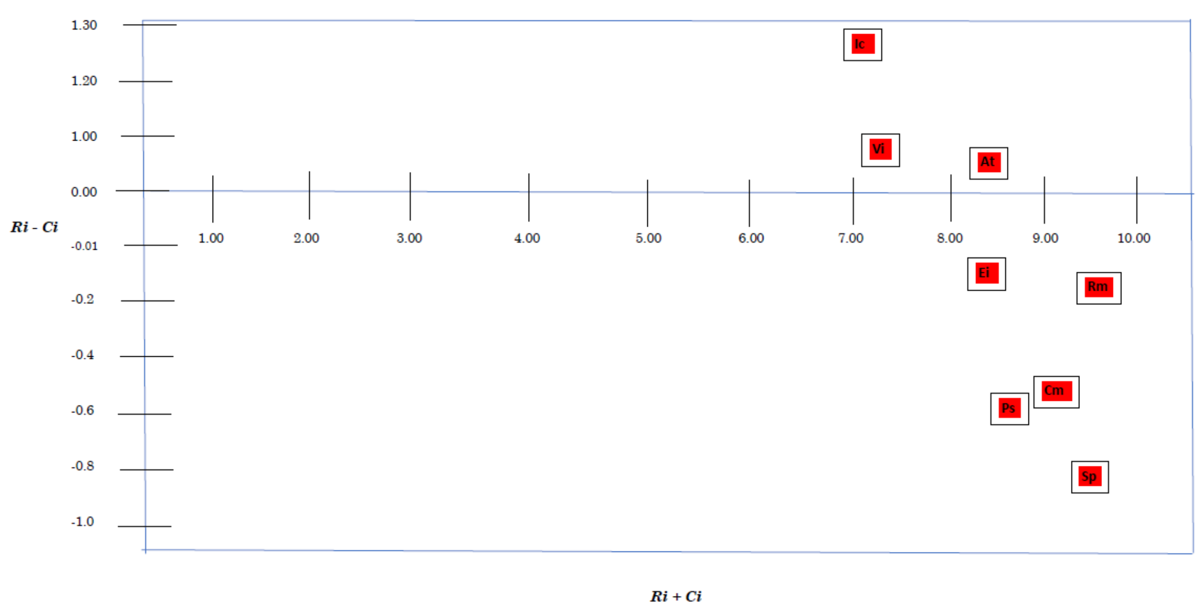


Figure 4.16 Cause and Effect Diagram

4.1.5 5D BIM Drivers Model

The model below shows the pictorial representation of the most influential drivers of 5D BIM for efficient construction project delivery. The drivers as reduced by factor analysis and further modeled using DEMATEL analysis has shown how the use of this drivers in series will bring about the efficient construction project delivery. The model is seen below;

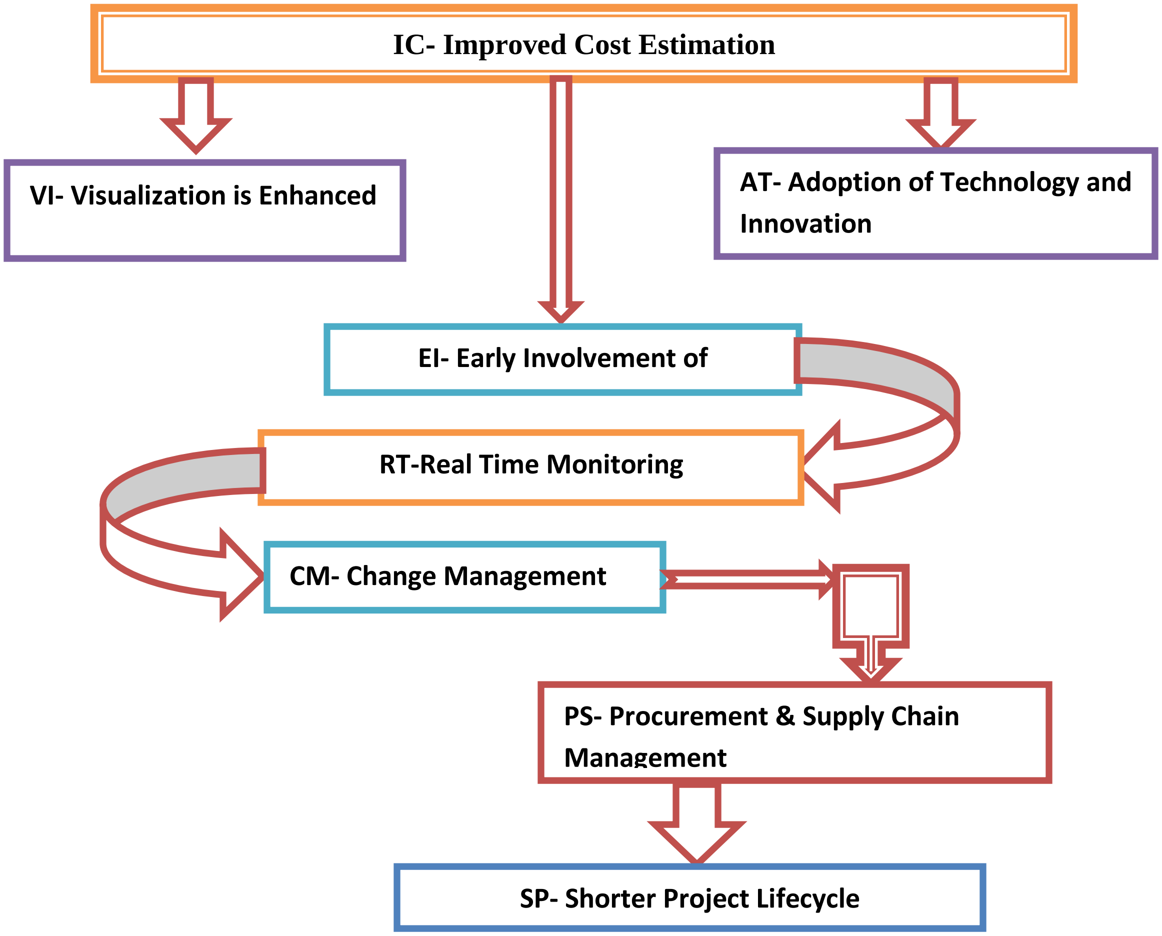


Figure 4.17 5D BIM Drivers Model

Source: Author's compilation (2023)

4.2 Results Discussion

The results obtained from the responses of professionals in various construction companies with respect to 5D BIM deployments in construction project, identification of 5D BIM drivers and modeling of the identified drivers, the findings of each of the objectives of this study is discussed below.

In terms of the respondents discipline, 25 (96.1)% are structural engineers, 16(84.2)% are Architects, 11(78.6)% are Builders, 7(77.7)% are Quantity surveyors, and lastly, 3(100)% are Project managers. The finding demonstrates that the respondents are registered professionals and as such they possess the technical knowledge needed to contribute to research, thus providing the needed insight into the research.

4.2.1 Evaluating the Extent of Deployment of 5D BIM on Construction Project Delivery in Nasarawa State.

With respect to this study, the extent of deployment of 5D BIM on construction project delivery in Nasarawa state as seen in the results above is very low. Majority of the respondents agreed that they are aware of 5D BIM in construction. But the bone of contention is if 5D BIM is deployed in their various construction projects or not. Majority of the respondents either disagreed or strongly disagreed that 5D BIM is recognized by their construction companies, the same thing goes to the usage of 5D BIM in the execution of projects the duration 5D BIM has been deployed by their construction companies, the acceptability of clients, the extent of how 5D BIM has helped in automated costing, how 5D BIM has eased up manual costing errors and the respondents acquaintance to 5D BIM in construction has been seen to be negative. Husin et al. (2019) stated that, 5D BIM on construction projects delivery is mostly deployed in areas like tendering documents, which is the most important source of data in making BIM quantity take off work accurately. Another way of deploying 5D in construction includes modeling raw material standards and update between designers and material product through BIM interface. To conclude, the results shows that 5D BIM is not deployed in construction projects in Nasarawa state.

4.2.2 Identifying the Drivers of 5D BIM on Construction Project Delivery in Nasarawa State.

From the findings with respect to identifying the drivers of 5D BIM in construction project delivery, it shows that the respondents have either disagreed or strongly disagreed to usage of the already identified drivers. Lee et al, (2016) in their work identified some drivers and have affirmed that 5D BIM is an emerging approach that is currently transforming construction industry. Some drivers which includes; integration of information, visualization of 5D BIM will significantly reduce barriers for clients to participate in project, therefore, it will increase clients satisfaction by bridging the gap expectation and actual project outcome Also, the factor analysis used to identify the drivers of 5D BIM on construction projects delivery has shown that the responses skewed right showing the negativity of the responses of the respondents. Also the factor analysis has grouped the eight factors that will be used to model the drivers using DEMATEL analysis. In factor analysis, twenty two drivers were subjected to principal component analysis using IBM SPSS statistics. The sustainability data shows that many of the coefficients have value of 0.5 and above. Using the Kaiser- meyer olkin (KMO) measure of sampling adequacy of 0.613 was obtained. The value has fallen between the desirable values of 0.6. It can also be seen that items had extracted eigenvalues less than 0.5 cut off point hence all the values are qualified for next analysis.

4.2.3 To Model the 5D BIM Drivers using DEMATEL Analysis

Raza Hoseini et al (2021), in their research implementation of building information modeling (BIM) using Hybrid Z-DEMATEL-ISM approach, applied DEMATEL and ISM approaches to find the most important challenges and influence challenges. The influence challenges which are the challenges that once decided upon addressed or prioritized over other factors and have the highest effect on other factors. Adversely, the influenced challenges are the ones that will be affected or changed most of the results of other factors changing. They also used the causal diagraph to identify the influence among various challenges. To model the drivers of 5D BIM, the DEMATEL analysis rates variables and their influence on the construction projects using linguistic scale value. The linguistic scale value is a five scale point that contains 0 as no influence, 1 as very low, 2 as low, 3 as high and 4 as very high influence. The eight factors extracted from the previous analysis (factor analysis) which includes, procurement and supply management, denoted by PS, real time monitoring as RM, Visualization enhancement as VI, adoption of technology as AT, change management as CM, Shorter project life cycle as SP, early involvement of contractors as EI, and lastly improved cost estimation as IC. The linguistic assessment of the evaluators of 5D BIM drivers has indicated in a diagonal view that PS id high, RM is very low, VI is high, AT is low, CM is also low, SP is very low, EI is high and IC has no influence.

The cause effect diagram also further explains the strength of the influence among 5D BIM drivers. Five factors fall below 0.00 margin with negative sign which falls within the effect which includes, EI, RM, PS, CM and SP while three factors fall above the 0.00 which is positive this factors include IC, VI, and AT

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion this research has provided an insight into the current state of 5D BIM application for efficient construction project delivery. This study has analyzed the extent of deployment of 5D BIM in construction project delivery. It has also identified the drivers of 5D BIM on construction project delivery and lastly the identified drivers were modeled using decision making trial and evaluation laboratory (DEMATEL).

The three different analysis as related to this research which includes descriptive statistics, factor analysis and DEMATEL analysis were used on each of the objectives of the study. From the results obtained, analyzed and discussed, the following conclusions were made;

a. The study evaluates the extent of deployment of 5D BIM on construction project delivery in Nasarawa state. It was observed that the extent of deployment of 5D BIM is very low and in some instances not used at all. Mustapha et.al. (2023) stated that implementation of 5D BIM in cost management of construction projects can present some challenges which includes the need for effective data integration and interoperability. This research concludes that the extent of deployment of 5D BIM in construction project in Nasarawa state is faced with the challenges of non-implementation by the construction companies, non-recognition of 5D BIM in construction by companies, non-acceptability of 5D BIM by some clients and non-acquaintance of professions to 5D BIM

b. The study also identifies twenty two drivers (22) of 5D BIM in construction projects which includes planning and design, procurement and supply chain management, project management and collaboration, technology and innovation, risk management, improved cost estimation among others. Hussain et.al. 2023 in his study with respect to 5D BIM cost in rail industry identified four (4) drivers which includes; quantity takeoff qualification, cost estimation, cost monitoring and control, lifecycle and cost analysis. Some of the identified drivers in his work are also mentioned in this research such as cost monitoring and control, and project lifecycle. As they also play a role in the efficient delivery of construction projects. Factor analysis was used to analyze the twenty two (22) drivers which were reduced to eight significant drivers.

c. DEMATEL analysis was used to model the eight factors extracted from the twenty two (22) drivers. The eight factors which include procurement and supply management, real time monitoring, visualization enhancement, adoption of technology and innovation, chain management, shorter project lifecycle, early involvement of contractors, and improved cost estimation were subjected to assessment using the linguistic scale variable of no influence, very low influence, low influence, high influence and very high influence. The eight factors sum up influences on 5D BIM drivers were seen to fall within the two categories of cause and effect. Three factors namely; visualization enhancement, adoption of technology and involvement of contractors fall within the cause section were as the remaining five factors fall within the effect section due to their low influences.

5.2 Recommendations

In the light of the above result of the data analysis, the study proffers the following recommendations;

a. With respect to the deployment of 5D BIM on construction project delivery in Nasarawa state the construction companies should make sure that they embrace digital modernization in construction, they should also make sure that there professionals are aware of 5D BIM, construction companies should provide lectures and seminars to educate their professionals and simple software applications and platforms for digital costing should be created for easy utilization.

b. With respect to the identified drivers of 5D BIM on construction project delivery, construction companies in Nasarawa state should make full utilization of these drivers as it was seen that non or only few of the drivers were used by some of the construction companies in a very negligible instance. Other drivers should be explored and utilized for easy and efficient delivery of projects.

c. With respect to modeling 5D BIM drivers on construction project delivery, the construction companies should utilized the drivers that have high influence on construction project delivery fully as their influence will adequately help in the efficiency of the construction project delivery.

5.3 Contribution to Knowledge

In this study, 5D BIM deployment on construction projects are expected to provide an efficient way of project delivery with the help of utilization of the identified drivers of 5D BIM.

This research made some contributions to the body of knowledge as follows;

a. The study has identified that most construction industries do not use 5D BIM in construction project delivery in Nasarawa state, thus providing the best ways construction companies can utilized 5D BIM in other to modernize their construction project and efficiently deliver them.

b. The study has also identified twenty two (22) drivers that can be used to efficiently deliver construction projects thus the utilization of these drivers by construction companies will immensely help in the efficient delivery of projects and digitalization of construction project works.

c. The twenty two (22) identified drivers were modeled and reduced to eight factors. The usage of this factor in construction project will clearly help in efficient delivery of projects as they are the most influential factors needed for efficient construction project delivery out of the twenty two drivers already identified.

d. Lastly, this research will shade more light to students of knowledge on 5D BIM and give them the urge of utilizing it in reality. The research will also help researchers on the extent of deployment of 5D BIM in Nigeria at large and particularly Nasarawa state. This research will also alert the general public the need to accept and implement 5D BIM in construction and will eventually help in the digitalization of construction project now and in the nearest future.

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APPENDIX 1
INTRODUCTION LETTER

Department of Project Management Technology,
Federal University of Technology
P.M.B. 1526
Owerri, Nigeria.
4th January 2023.

To Whom It May Concern

Dear Sir/Madam,

COLLECTION OF DATA FOR MSC RESEARCH

I am **Muhammad AbdulqadirKabir**, an MSC student of the Department of Project Management Technology, School of Management Technology of the above School. This questionnaire is meant to collect data for a research titled **"Modeling 5D BIM Drivers for Efficient Construction Project Delivery"**.

The questions are therefore intended to solicit information from you/ your organization so that the objectives of the research work can be achieved.

The result of this thesis work will eventually be of immense benefit to both the public and private construction industry in particular and the Country at large. You are further assured that all the information that will be treated in strict confidence. It would therefore be appreciated if you could provide the needed information with utmost clarity and sincerity.

Thank you in anticipation of your co-operation.

Yours Faithfully

Muhammad AbdulqadirKabir (Project Management Technology) Candidate
07038723308

A STUDY ON THE MODELING OF 5D BIM DRIVERS FOR EFFICIENT CONSTRUCTION PROJECT DELIVERY IN NASARAWA STATE.

SECTION A

Demographic Information of Respondents

1. Name of Company/ Industry …………………………………...

2. Location of Company/Establishment ....,..

3. Academic Qualification: a). Bsc/B. Tech [ ]. b). Msc [ ]. c). MBA. [ ]. d). Ph.D. [ ]. e). Others [ ]

4. Years of Experience: a). Below 5years [ ]. b). 6-10years [ ]. c) 11-15 years [ ]. d). 16-20years [ ] e). Above 20years [ ]

5. Which group of professional/ participation do you belong to? a). Architects [ ]. b) Engineers [ ] c). Quantity Surveyors [ ] d). Project Managers [ ] e). Builders [ ]

6. Which group of regulatory body in the construction industry I'm Nigeria do you belong to?

a) The Nigerian Institute of Architects [ ] b) The Nigerian Society of Engineers NSE [ ] c) The Nigerian Institute of Quantity Surveyors NIQS [ ] d) Chattered Institute of Project Managers. [ ] e). Nigerian Institute of Builders [ ]

SECTION B: Extent of deployment of 5D BIM in construction Project delivery in Nasarawa State.

Listed below are some likely ways of deployment of 5D BIM in Construction industries. Kindly rate using the Likert scale five provided below.

5 (SA)= Strongly Agreed, 4(A)= Agreed, 3(N)= Neutral, 2(DA)= Disagreed, 1(SD)= Strongly Disagreed.

S/N	Ways of Deployment of 5D BIM	5 (SA)	4 (A)	3 (N)	2 (DA)	1 (SD)
1	Are you aware of 5D BIM in construction?					
2	5D BIM is known and recognized by your construction company					
3	5D BIM is used in the execution of construction projects by your company					
4	5D BIM usage is constant and mandatory in your construction company					
5	5D BIM deployment has been used in your organization for long					
6	5D BIM is always acceptable by your clients					
7	5D BIM usage has help in automated costing of construction projects in your organization					
8	5D BIM usage has eased up manual costing errors in construction projects in your organization					
9	Your acquaintance with 5D BIM I'm construction project is high					

Please state any other way you think 5D BIM is deployed by your company that have not been mentioned above

...................,..
....

SECTION C. Below are Identified 5D BIM drivers in construction industries, kindly rate using the Likert scale five below

S/N	Identified 5D BIM drivers in construction projects	5 (SA)	4 (A)	3 (N)	2 (DA)	1 (SD)
1	**Visualization is enhanced** in construction projects for project delivery					
2	**Accurate quantity takeoff** is a major financial driver in construction projects					
3	**Efficient schedule planning** is used as a Management tool driver in construction projects					
4	**Enhanced project coordination** is also used in construction projects by your company					
5	**Improved cost estimation** is a financial driver used by your company for efficient construction project					

6	**Management of risk** in construction projects is well utilized by your company					
7	There is **Adoption of technology and innovation** in construction industry					
8	**Project Management collaboration** such as clear communication, regular progress monitoring & collaboration amongst stakeholders					
9	**Procurement and supply management** is also a driver used by your company					
10	**Planning and design** is a 5D BIM driver widely used by your company					
11	**Real time monitoring** is a driver used in monitoring projects by your company					
12	**Enhanced Communication** drivers are used to ease communication in your company					
13	Your company uses **Resource allocation** for efficient construction					
14	Your company uses **Change Management** in construction					
15	**Heightened cost forecasting** is used as a financial driver for efficient construction project					
16	**Shorter project life cycle** driver is a product of 5D BIM					
17	**Multi platform Access** driver enhances smooth construction projects					
18	**Early involvement of contractors** is also a 5D BIM driver used by your company					
19	**The Clash detection and clash avoidance** driver is useful in your construction projects					
20	**Construction schedule optimization** driver is deployed by your company					
21	**Clear project objectives and scope definition** is also a 5D BIM driver used by your company					
22	5D BIM helps in the provision of **Availability of accurate and updated project information** in construction projects					

Please state any other 5D BIM drivers deployed by your company that have not been mentioned above ....,...

APPENDIX II

INTERVIEW RESPONSE ON PERFORMANCE DATA FOR FIVE COMPANIES

Five companies' currently undertaking major projects in Nasarawa state have been consulted and interview questions and responses on the company's performance data are seen below.

Table 4.14 Response from Fortbuild ltd.

S/N	INTERVIEW QUESTIONS	RESPONSES
1	What is the name of your company?	FortBuild Ltd
2	What is your rank in the company?	Senior Quantity Surveyor
3	Can you disclose the financial health of your company? What is the company's worth/value in Naira?	One billion naira
4	What is the estimated budget of this current project?	1.2 Billion
5	Do you feel like the project is staying within the stated budget?	No
6	What challenges have you encountered in keeping the project within budget?	Inflation has always been the major challenge
7	What are some ways this project could be more cost effective?	By reducing unnecessary running expenditures (running cost)
8	How does the cost of this project compare to similar projects?	It is a class above its contemporaries
9	Do you think this project is over budgeted or under budgeted?	The project seem to be under budgeted as some of the things been done are not part of the initial budget
10	If this Project is over budgeted can you tell more about the areas that are over budgeted?	
11	Which specific activities or tasks are driving the overspending?	
12	Is the project team aware of the overspending and working to address it?	
13	Do you think the project is staying on schedule?	Yes
14	Do you feel like the project is staying in track with the planned schedule?	Averagely
15	What is the relationship between the cost metric in the 5D BIM model and the project's actual cost?	It seems fair

Table 4.15 Response from Gryn Brick Nig. Ltd.

S/N	INTERVIEW QUESTIONS	RESPONSES
1	What is the name of your company?	Gryn brick Nigeria limited
2	What is your rank in the company?	Construction manager
3	Can you disclose the financial health of your company? What is the company's worth/value in Naira?	No i can't
4	What is the estimated budget of this current project?	1 billion
5	Do you feel like the project is staying within the stated budget?	No
6	What challenges have you encountered in keeping the project within budget?	Inflation and continuous high cost of materials
7	What are some ways this project could be more cost effective?	Buying of materials in bulk, sticking to the time frame of program of work
8	How does the cost of this project compare to similar projects?	Higher compare to others
9	Do you think this project is over budgeted or under budgeted?	Under budget
10	If this Project is over budgeted can you tell more about the areas that are over budgeted ?	
11	Which specific activities or tasks are driving the overspending?	Reinforcement and finishing material
12	Is the project team aware of the overspending and working to address it?	
13	Do you think the project is staying on schedule?	Yes
14	Do you feel like the project is staying in track with the planned schedule?	Yes
15	What is the relationship between the cost metric in the 5D BIM model and the project's actual cost?	The quantity surveyor will be to answer this

Table 4.16 Response from Muhafa Global Limited

S/N	INTERVIEW QUESTIONS	RESPONSES
1	What is the name of your company?	Muhafa Global limited
2	What is your rank in the company?	Senior Engineer
3	Can you disclose the financial health of your company? What is the company's worth/value in Naira?	2 billion Naira
4	What is the estimated budget of this current project?	450 million
5	Do you feel like the project is staying within the stated budget?	No
6	What challenges have you encountered in keeping the project within budget?	Inflation which leads to the rise of prices of construction materials
7	What are some ways this project could be more cost effective?	Sub-budget to cover for the rise in price of construction matrials
8	How does the cost of this project compare to similar projects?	The cost is very low
9	Do you think this project is over budgeted or under budgeted?	Under-budgeted
10	If this Project is over budgeted can you tell more about the areas that are over budgeted?	It is under-budgeted
11	Which specific activities or tasks are driving the overspending?	Labour cost
12	Is the project team aware of the overspending and working to address it?	Yes
13	Do you think the project is staying on schedule?	No
14	Do you feel like the project is staying on track with the planned schedule?	No
15	What is the relationship between the cost metric in the 5D BIM model and the project's actual cost?	

Table 4.17 Response from Cops ltd Engineering and Construction services

S/N	INTERVIEW QUESTIONS	RESPONSES
1	What is the name of your company?	Cops ltd. Engineering and construction services
2	What is your rank in the company?	Chief Engineer
3	Can you disclose the financial health of your company? What is the company’s worth/value in Naira?	10 billion
4	What is the estimated budget of this current project?	The current one in lafian is 1 billion and the others at Akwanga and Nasarawa are 700million naira each
5	Do you feel like the project is staying within the stated budget?	Yes
6	What challenges have you encountered in keeping the project within budget?	Inflationnand rise in prices of materials and labour cost
7	What are some ways this project could be more cost effective?	Increasing Contingency cost
8	How does the cost of this project compare to similar projectsz	Almost similar and the same
9	Do you think this project is over budgeted or under budgeted?	The project is neither over budgeted nor under budgeted
10	If this Project is over budgeted can you tell more about the areas that are over budgeted ?	
11	Which specific activities or tasks are driving the overspending?	Purchase and transportation
12	Is the project team aware of the overspending and working to address it?	Yes
13	Do you think the project is staying on schedule?	Yes
14	Do you feel like the project is staying in track with the planned schedule?	Yes
15	What is the relationship between the cost metric in the 5D BIM model and the project's actual cost?	It is neutral at the moment. Might change before the project is completed

Table 4.18 Response from One city construction ltd.

S/N	INTERVIEW QUESTIONS	RESPONSES
1	What is the name of your company?	One city construction ltd
2	What is your rank in the company?	Builder
3	Can you disclose the financial health of your company? What is the company's worth/value in Naira?	No
4	What is the estimated budget of this current project?	Don't know the exact budget, but it is around 2 billion
5	Do you feel like the project is staying within the stated budget?	Yes
6	What challenges have you encountered in keeping the project within budget?	Minimizing labour cost
7	What are some ways this project could be more cost effective?	Making use of contingency budget
8	How does the cost of this project compare to similar projects?	I really cant say
9	Do you think this project is over budgeted or under budgeted?	It is neither of the two
10	If this Project is over budgeted can you tell more about the areas that are over budgeted ?	
11	Which specific activities or tasks are driving the overspending?	Transportation cost of building materials
12	Is the project team aware of the overspending and working to address it?	
13	Do you think the project is staying on schedule?	Yes
14	Do you feel like the project is staying in track with the planned schedule?	Yes
15	What is the relationship between the cost metric in the 5D BIM model and the project's actual cost?	I don't know

APPENDIX III

Factor analysis results output/printout

Raw input data from IBM SPSS Statistics Version 25.0

	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22
1	5.00	3.00	5.00	4.00	5.00	4.00	5.00	4.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00
2	4.00	2.00	5.00	4.00	5.00	2.00	5.00	4.00	2.00	3.00	4.00	4.00	3.00	5.00	4.00	5.00	4.00	4.00	3.00	4.00	4.00	3.00	5.00
3	4.00	3.00	4.00	3.00	5.00	3.00	4.00	3.00	3.00	5.00	2.00	5.00	4.00	5.00	2.00	5.00	4.00	3.00	5.00	2.00	5.00	4.00	5.00
4	3.00	5.00	5.00	4.00	4.00	4.00	4.00	4.00	4.00	5.00	4.00	5.00	4.00	5.00	3.00	4.00	3.00	4.00	5.00	4.00	5.00	4.00	5.00
5	5.00	3.00	5.00	4.00	5.00	4.00	4.00	5.00	3.00	4.00	3.00	4.00	4.00	5.00	4.00	4.00	4.00	3.00	4.00	3.00	4.00	4.00	5.00
6	4.00	3.00	4.00	4.00	4.00	3.00	5.00	4.00	4.00	4.00	4.00	4.00	3.00	3.00	3.00	4.00	4.00	2.00	4.00	4.00	4.00	3.00	3.00
7	5.00	4.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00	5.00	4.00	4.00	4.00	5.00	3.00	4.00	3.00	3.00	5.00	4.00	4.00	4.00	5.00
8	4.00	3.00	5.00	3.00	5.00	4.00	4.00	5.00	3.00	3.00	3.00	4.00	4.00	3.00	4.00	5.00	4.00	3.00	3.00	3.00	4.00	4.00	3.00
9	5.00	4.00	5.00	4.00	4.00	3.00	5.00	4.00	4.00	4.00	5.00	5.00	4.00	5.00	3.00	5.00	4.00	5.00	4.00	5.00	5.00	4.00	5.00
10	3.00	4.00	4.00	3.00	4.00	3.00	4.00	4.00	4.00	5.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00	4.00	5.00	4.00	5.00	4.00	4.00
11	5.00	4.00	3.00	4.00	4.00	4.00	5.00	3.00	2.00	5.00	4.00	4.00	5.00	5.00	4.00	5.00	5.00	4.00	5.00	4.00	4.00	5.00	5.00
12	4.00	4.00	5.00	4.00	5.00	4.00	4.00	4.00	4.00	5.00	4.00	5.00	4.00	5.00	3.00	4.00	3.00	4.00	5.00	4.00	5.00	4.00	5.00
13	4.00	3.00	4.00	4.00	4.00	3.00	4.00	4.00	3.00	5.00	2.00	5.00	4.00	3.00	4.00	5.00	4.00	5.00	5.00	2.00	5.00	4.00	3.00
14	4.00	4.00	5.00	3.00	3.00	5.00	4.00	5.00	4.00	5.00	3.00	4.00	3.00	5.00	3.00	5.00	4.00	4.00	5.00	3.00	4.00	3.00	5.00

15	5.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	3.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00	5.00	3.00	4.00	5.00	4.00	4.00
16	3.00	3.00	4.00	4.00	4.00	4.00	5.00	4.00	3.00	5.00	3.00	5.00	4.00	5.00	4.00	5.00	4.00	4.00	5.00	3.00	5.00	4.00	5.00
17	5.00	4.00	5.00	3.00	4.00	2.00	4.00	3.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00
18	5.00	4.00	5.00	4.00	4.00	4.00	5.00	5.00	4.00	3.00	4.00	4.00	3.00	5.00	4.00	5.00	4.00	4.00	3.00	4.00	4.00	3.00	5.00
19	4.00	4.00	4.00	2.00	5.00	4.00	5.00	4.00	4.00	5.00	2.00	5.00	4.00	5.00	2.00	5.00	4.00	3.00	5.00	2.00	5.00	4.00	5.00
20	4.00	4.00	5.00	4.00	5.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	3.00	4.00	3.00	4.00	5.00	4.00	5.00	4.00	5.00
21	5.00	4.00	4.00	4.00	4.00	2.00	4.00	2.00	4.00	4.00	3.00	4.00	4.00	5.00	4.00	4.00	4.00	3.00	4.00	3.00	4.00	4.00	5.00
22	3.00	3.00	5.00	3.00	5.00	4.00	5.00	4.00	3.00	4.00	4.00	4.00	3.00	3.00	3.00	4.00	4.00	2.00	4.00	4.00	4.00	3.00	3.00
23	5.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00	4.00	5.00	4.00	4.00	4.00	5.00	3.00	4.00	3.00	3.00	5.00	4.00	4.00	4.00	5.00
24	4.00	2.00	4.00	3.00	5.00	3.00	5.00	3.00	2.00	5.00	3.00	5.00	4.00	5.00	4.00	4.00	4.00	4.00	5.00	3.00	5.00	4.00	5.00
25	4.00	4.00	5.00	5.00	5.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00	4.00	3.00	3.00	4.00	4.00	3.00	4.00	4.00	4.00	4.00	3.00
26	5.00	4.00	5.00	4.00	4.00	3.00	4.00	3.00	4.00	5.00	4.00	5.00	5.00	4.00	5.00	5.00	4.00	4.00	5.00	4.00	5.00	5.00	4.00
27	5.00	5.00	4.00	5.00	5.00	5.00	5.00	5.00	5.00	4.00	3.00	5.00	3.00	5.00	4.00	5.00	4.00	4.00	4.00	3.00	5.00	3.00	5.00
28	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00
29	5.00	4.00	5.00	4.00	4.00	5.00	4.00	5.00	4.00	3.00	4.00	4.00	3.00	5.00	4.00	5.00	4.00	4.00	3.00	4.00	4.00	3.00	5.00
30	4.00	4.00	4.00	5.00	5.00	4.00	5.00	4.00	4.00	5.00	2.00	5.00	4.00	5.00	2.00	5.00	4.00	3.00	5.00	2.00	5.00	4.00	5.00
31	5.00	3.00	5.00	4.00	4.00	2.00	4.00	3.00	3.00	5.00	4.00	5.00	4.00	5.00	3.00	4.00	3.00	4.00	5.00	4.00	5.00	4.00	5.00
32	3.00	4.00	5.00	4.00	4.00	4.00	5.00	5.00	4.00	4.00	3.00	4.00	4.00	5.00	4.00	4.00	4.00	3.00	4.00	3.00	4.00	4.00	5.00
33	5.00	4.00	5.00	1.00	5.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00	3.00	3.00	3.00	4.00	4.00	2.00	4.00	4.00	4.00	3.00	3.00
34	5.00	4.00	5.00	4.00	5.00	5.00	4.00	5.00	4.00	5.00	4.00	4.00	4.00	5.00	3.00	4.00	3.00	3.00	5.00	4.00	4.00	4.00	5.00

35	4.00	3.00	4.00	5.00	4.00	2.00	4.00	3.00	3.00	3.00	3.00	4.00	4.00	3.00	4.00	5.00	4.00	3.00	3.00	3.00	4.00	4.00	3.00
36	3.00	4.00	5.00	4.00	4.00	4.00	5.00	4.00	4.00	4.00	5.00	5.00	4.00	5.00	3.00	5.00	4.00	5.00	4.00	5.00	5.00	4.00	5.00
37	5.00	4.00	4.00	5.00	5.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00	4.00	5.00	4.00	5.00	4.00	4.00
38	4.00	5.00	5.00	4.00	4.00	5.00	4.00	4.00	5.00	5.00	4.00	4.00	5.00	5.00	4.00	5.00	5.00	4.00	5.00	4.00	4.00	5.00	5.00
39	5.00	4.00	5.00	4.00	5.00	4.00	5.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	3.00	4.00	3.00	4.00	5.00	4.00	5.00	4.00	5.00
40	5.00	4.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00	5.00	2.00	5.00	4.00	3.00	4.00	5.00	4.00	5.00	5.00	2.00	5.00	4.00	3.00
41	4.00	4.00	5.00	4.00	3.00	4.00	5.00	4.00	4.00	5.00	3.00	4.00	3.00	5.00	3.00	5.00	4.00	4.00	5.00	3.00	4.00	3.00	5.00
42	5.00	5.00	5.00	4.00	3.00	4.00	5.00	4.00	5.00	3.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00	5.00	3.00	4.00	5.00	4.00	4.00
43	5.00	4.00	4.00	5.00	3.00	4.00	5.00	4.00	4.00	5.00	3.00	5.00	4.00	5.00	4.00	5.00	4.00	4.00	5.00	3.00	5.00	4.00	5.00
44	4.00	5.00	5.00	4.00	4.00	5.00	4.00	4.00	5.00	5.00	3.00	5.00	4.00	5.00	4.00	4.00	4.00	4.00	5.00	3.00	5.00	4.00	5.00
45	3.00	4.00	5.00	4.00	4.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00	4.00	3.00	3.00	4.00	4.00	3.00	4.00	4.00	4.00	4.00	3.00
46	5.00	3.00	4.00	5.00	3.00	5.00	4.00	3.00	3.00	5.00	4.00	5.00	5.00	4.00	5.00	5.00	4.00	4.00	5.00	4.00	5.00	5.00	4.00
47	4.00	4.00	5.00	4.00	4.00	5.00	4.00	4.00	4.00	4.00	3.00	5.00	3.00	3.00	5.00	3.00	3.00	3.00	4.00	3.00	5.00	3.00	3.00
48	5.00	4.00	5.00	5.00	3.00	4.00	5.00	3.00	4.00	5.00	4.00	5.00	4.00	4.00	5.00	4.00	4.00	4.00	5.00	4.00	5.00	4.00	4.00
49	5.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00	4.00	3.00	4.00	4.00	3.00	4.00	4.00	3.00	4.00	4.00	3.00	4.00	4.00	3.00	4.00
50	3.00	4.00	4.00	5.00	4.00	4.00	3.00	5.00	4.00	5.00	2.00	3.00	4.00	5.00	4.00	5.00	4.00	2.00	5.00	2.00	3.00	4.00	5.00
51	5.00	3.00	5.00	4.00	4.00	4.00	4.00	5.00	3.00	5.00	4.00	5.00	4.00	3.00	4.00	4.00	3.00	4.00	5.00	4.00	5.00	4.00	3.00
52	4.00	4.00	5.00	4.00	3.00	3.00	3.00	4.00	4.00	4.00	3.00	4.00	4.00	5.00	2.00	3.00	4.00	3.00	4.00	3.00	4.00	4.00	5.00
53	5.00	3.00	4.00	5.00	4.00	4.00	2.00	4.00	3.00	4.00	4.00	5.00	3.00	5.00	4.00	5.00	4.00	4.00	4.00	4.00	5.00	3.00	5.00
54	4.00	2.00	4.00	3.00	3.00	3.00	3.00	4.00	2.00	5.00	4.00	4.00	4.00	5.00	4.00	5.00	4.00	4.00	5.00	4.00	4.00	4.00	5.00

55	4.00	3.00	4.00	5.00	3.00	4.00	5.00	3.00	3.00	3.00	3.00	4.00	4.00	4.00	2.00	4.00	3.00	3.00	3.00	3.00	4.00	4.00	4.00
56	5.00	3.00	4.00	4.00	4.00	5.00	4.00	4.00	3.00	5.00	4.00	5.00	3.00	4.00	4.00	5.00	5.00	4.00	5.00	4.00	5.00	3.00	4.00
57	5.00	4.00	5.00	4.00	4.00	5.00	5.00	4.00	4.00	5.00	4.00	5.00	4.00	3.00	3.00	5.00	3.00	4.00	5.00	4.00	5.00	4.00	3.00
58	5.00	2.00	5.00	4.00	4.00	5.00	4.00	4.00	2.00	4.00	3.00	5.00	3.00	3.00	5.00	3.00	3.00	3.00	4.00	3.00	5.00	3.00	3.00
59	5.00	3.00	4.00	3.00	4.00	4.00	5.00	4.00	3.00	5.00	4.00	5.00	4.00	4.00	5.00	4.00	4.00	4.00	5.00	4.00	5.00	4.00	4.00
60	3.00	4.00	5.00	4.00	3.00	5.00	4.00	3.00	4.00	3.00	4.00	4.00	3.00	4.00	4.00	3.00	4.00	4.00	3.00	4.00	4.00	3.00	4.00
61	5.00	3.00	5.00	4.00	4.00	5.00	4.00	4.00	3.00	5.00	2.00	3.00	4.00	5.00	4.00	5.00	4.00	2.00	5.00	2.00	3.00	4.00	5.00
62	4.00	4.00	4.00	4.00	3.00	4.00	5.00	3.00	4.00	5.00	4.00	5.00	4.00	3.00	4.00	4.00	3.00	4.00	5.00	4.00	5.00	4.00	3.00
63	5.00	4.00	4.00	5.00	3.00	3.00	4.00	4.00	4.00	4.00	3.00	4.00	4.00	5.00	2.00	3.00	4.00	3.00	4.00	3.00	4.00	4.00	5.00
64	4.00	3.00	5.00	3.00	3.00	5.00	3.00	3.00	3.00	4.00	4.00	5.00	3.00	5.00	4.00	5.00	4.00	4.00	4.00	4.00	5.00	3.00	5.00
65	5.00	4.00	5.00	4.00	4.00	5.00	4.00	4.00	4.00	5.00	4.00	4.00	4.00	5.00	4.00	5.00	4.00	4.00	5.00	4.00	4.00	4.00	5.00
66	3.00	4.00	4.00	3.00	4.00	4.00	3.00	4.00	4.00	3.00	3.00	4.00	4.00	4.00	2.00	4.00	3.00	3.00	3.00	3.00	4.00	4.00	4.00
67	5.00	2.00	3.00	4.00	5.00	4.00	5.00	4.00	2.00	5.00	4.00	5.00	3.00	4.00	4.00	5.00	5.00	4.00	5.00	4.00	5.00	3.00	4.00
68	5.00	4.00	5.00	4.00	3.00	4.00	4.00	3.00	4.00	5.00	4.00	5.00	4.00	3.00	3.00	5.00	3.00	4.00	5.00	4.00	5.00	4.00	3.00
69	4.00	3.00	4.00	4.00	5.00	2.00	3.00	4.00	3.00	4.00	3.00	5.00	3.00	3.00	5.00	3.00	3.00	3.00	4.00	3.00	5.00	3.00	3.00
70	4.00	4.00	5.00	3.00	5.00	4.00	5.00	4.00	4.00	5.00	4.00	5.00	4.00	4.00	5.00	4.00	4.00	4.00	5.00	4.00	5.00	4.00	4.00
71	5.00	4.00	4.00	4.00	5.00	4.00	5.00	4.00	4.00	3.00	4.00	4.00	3.00	4.00	4.00	3.00	4.00	4.00	3.00	4.00	4.00	3.00	4.00

[DataSet1] C:\Users\HP\Documents\Students Assignment & Works 2\Abdul's Factor Analysis.sav

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.613
Bartlett's Test of Sphericity	Approx. Chi-Square	5447.829
	Df	231
	Sig.	.000

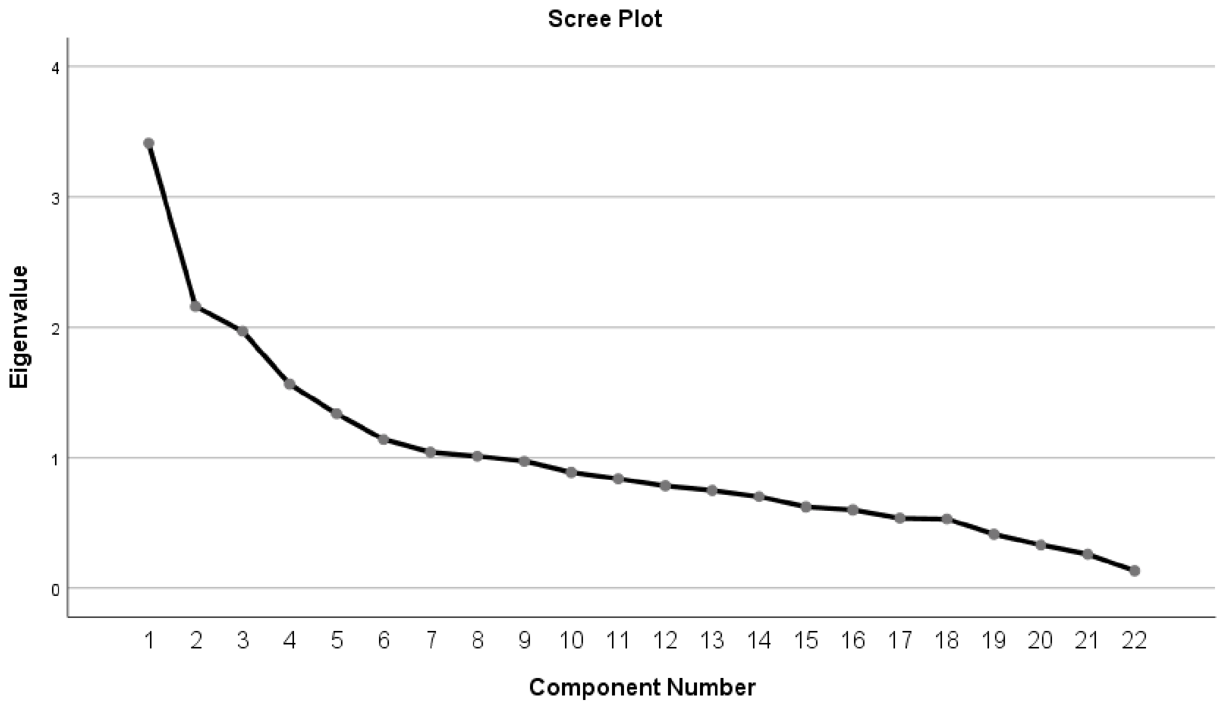
Communalities

	Initial	Extraction
Visualization is enhanced	1.000	.664
Accurate quantity takeoff	1.000	.649
Efficient schedule planning	1.000	.538
Enhanced project coordination	1.000	.619
Improved cost estimation	1.000	.628
Management of risk	1.000	.591
Adoption of technology and innovation	1.000	.553
Project Management collaboration	1.000	.514
Procurement and supply management	1.000	.500
Planning and design	1.000	.619
Real time monitoring	1.000	.802
Enhanced Communication	1.000	.869
Resource allocation	1.000	.875

Change Management	1.000	.848
Heightened cost forecasting	1.000	.856
Shorter project life cycle	1.000	.546
Multi-platform Access	1.000	.562
Early involvement of contractors	1.000	.593
The Clash detection and clash avoidance	1.000	.584
Construction schedule optimization	1.000	.546
Clear project objectives and scope definition	1.000	.571
Availability of accurate and updated project information	1.000	.633
Extraction Method: Principal Component Analysis.		

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.413	15.512	15.512	3.413	15.512	15.512	2.118	9.625	9.625
2	2.160	9.816	25.328	2.160	9.816	25.328	1.939	8.813	18.438
3	1.970	8.955	34.284	1.970	8.955	34.284	1.921	8.734	27.171
4	1.565	7.112	41.396	1.565	7.112	41.396	1.861	8.461	35.632
5	1.338	6.080	47.475	1.338	6.080	47.475	1.764	8.016	43.648
6	1.140	5.183	52.658	1.140	5.183	52.658	1.408	6.399	50.047
7	1.043	4.741	57.400	1.043	4.741	57.400	1.361	6.185	56.232
8	1.011	4.596	61.996	1.011	4.596	61.996	1.268	5.764	61.996
9	.973	4.423	66.419						
10	.888	4.036	70.455						
11	.838	3.811	74.267						
12	.784	3.564	77.831						
13	.750	3.408	81.239						
14	.702	3.190	84.428						

15	.622	2.828	87.257						
16	.600	2.726	89.983						
17	.537	2.439	92.422						
18	.530	2.408	94.830						
19	.414	1.881	96.711						
20	.331	1.505	98.216						
21	.260	1.183	99.398						
22	.132	.602	100.000						
Extraction Method: Principal Component Analysis.									



Component Matrix[a]								
	Component							
	1	2	3	4	5	6	7	8
Visualization is enhanced	.794							
Accurate quantity takeoff	.732							
Efficient schedule planning	.625							
Enhanced project coordination	.666							
Improved cost estimation		.911						
Management of risk		.909						
Adoption of technology and innovation			.653					

Project Management collaboration			.552					
Procurement and supply management				.921				
Planning and design				.913				
Real time monitoring					.746			
Enhanced Communication					.708			
Resource allocation					.630			
Change Management						.679		
Heightened cost forecasting						.671		
Shorter project life cycle							.743	
Multi-platform Access							.542	
Early involvement of contractors								.715
The Clash detection and clash avoidance								.711
Construction schedule optimization								.675
Clear project objectives and scope definition								.615
Availability of accurate and updated project information								.521
Extraction Method: Principal Component Analysis.								
a. 8 components extracted.								

APPENDIX I- Raw Data Set for Fuzzy DEMATEL

```
[DataSet2] C:\Users\Muhammad Abdulqadir Kabir\My Documents\Modeling 5D
BIM Drivers for Efficient Construction Project Delivery.II.sav
```

S/N	5D BIM drivers for Efficient Construction Project Delivery	Code
1	Procurement and supply management	Ps
2	Real time monitoring	Rm
3	Visualization is enhanced	Vi
4	Adoption of technology and innovation	At
5	Change Management	Cm
6	Shorter project life cycle	Sp
7	Early involvement of contractors	Ei
8	Improved cost estimation	Ic

Rating Scale

Variable	Influence score
No influence	0
Very low influence	1
Low influence	2
High influence	3
Very high influence	4

Linguistic assessment of the evaluators' opinion (average) of Drivers of 5D-BIM

	Ps	**Rm**	**Vi**	**At**	**Cm**	**Sp**	**Ei**	**Ic**
Ps	H	VH	NO	L	NO	H	VH	H
Rm	L	VL	VH	H	H	H	NO	H
Vi	NO	NO	H	NO	VH	VH	NO	NO
At	NO	NO	L	L	NO	H	H	L
Cm	L	L	NO	VL	L	L	L	VL
Sp	VL	H	VH	NO	H	VL	VH	H
Ei	NO	H	H	NO	NO	L	H	L
Ic	NO	H	VH	NO	L	NO	L	NO

Rating Scale

Variable	Linguistic Scale	Influence score
No influence	NO	0
Very low influence	VL	1
Low influence	L	2
High influence	H	3
Very high influence	VH	4

Table of 5D BIM drivers for Efficient Construction Project Delivery

S/N	**5D BIM drivers for Efficient Construction Project Delivery**	Procurement and Supply Management	Real Time Monitoring	Visualization is Enhanced	Adoption of Technology and Innovation	Change Management	Shorter Project Life Cycle	Early Involvement of Contractors	Improved Cost Estimation
1	Procurement and Supply Management								
2	Real Time Monitoring								
3	Visualization is Enhanced								
4	Adoption of Technology and Innovation								
5	Change Management								
6	Shorter Project Life Cycle								

7	Early Involvement of Contractors								
8	Improved Cost Estimation								