Evaluation of the Integration of Building Information Modelling and Virtual Design and Construction for Project Efficiency: An Analysis of the Malaysian Construction Industry

Lynne Mbaika Musembi
Taylors University, No.1, Jalan Taylor's, Subang Jaya, 47500, MALAYSIA
Email: penerbit.uthm.edu.my
*Corresponding Author Email: author@organization.edu.co

Abstract
This study explores the integration of Virtual Design and Construction (VDC) and Building Information Modelling (BIM) in Malaysia's construction sector, focusing on long-term sustainability and implementation challenges. While VDC and BIM have gained global recognition for enhancing project efficiency, reducing costs, and improving outcomes, unresolved issues persist, particularly regarding their impacts beyond economic benefits. The study's main objective is to evaluate how VDC and BIM influence construction costs, process efficiency, and sustainable practices in Malaysia. A key challenge in integrating these technologies involves adapting traditional workflows to VDC and BIM's collaborative nature, which is often hindered by stakeholder resistance and infrastructure limitations. To investigate these concerns, a qualitative research approach is adopted, using semi-structured interviews with professionals across the Architecture, Engineering, and Construction (AEC) sectors. This method facilitates a detailed understanding of how VDC and BIM integration impacts project execution, including factors such as waste reduction and stakeholder collaboration. The anticipated outcomes include a nuanced perspective on both the advantages and limitations of VDC and BIM in Malaysia's construction industry. Findings are expected to highlight the need for improved training, infrastructure upgrades, and policy development to support successful adoption. By providing valuable insights for industry professionals and policymakers, this study aims to bridge current research gaps and guide future advancements in construction technology, positioning Malaysia as a leader in sustainable, technology-driven construction practices.
Keywords: Building Information Modelling (BIM), Virtual Design and Construction (VDC), Project Efficiency, Construction Project Management, Malaysian Construction Industry, Digital Construction Technologies

Introduction
This research elaborates on the overall framework that integrates BIM and VDC in the construction industry. The body of existing literature related to the integration of VDC and

BIM is discussed in great detail in this chapter for better understanding of the complex web of information. Since the evolution of technology changes the AEC sectors, it becomes necessary to control the digital aspects and interoperability of the technology. It reviews the various literature shedding light on several challenges relating to the integration for sustainability, and the long-term advantages of sustainability.

Background of the Study
This section outlines the background study on Virtual Design and Construction, Building Information Modelling and Digital Construction in the Malaysian Construction Industry.

Virtual Design and Construction
The use of integrated multi-disciplinary performance models of design-construction projects to provide digital, visual representations of a construction project is known as virtual design and construction. The phrase "Virtual Design and Construction" was first coined in 2001 as part of the construction methodologies of Stanford University's Centre for Integrated Facility Engineering or CIFE and has ever since been one of the common terminologies employed for study (Kunz and Fischer, 2020) (Garcia *et al.*, 2004)

While the relationships between BIM and VDC have been greatly studied, little emphasis has been placed on the nature of those relationships and what kinds of intellectual frameworks underpin them. A better understanding of this interaction would not only allow AEC stakeholders to understand the frameworks of this interaction better but also increase the adoption of BIM and VDC. (C. Mourgues 2021). Gantt charts, printed drawings, and textual specifications are examples of traditional media that are typically used in information management for construction projects. These, however, offer limited opportunities for information exchange among AEC professionals (Kähkönen 2003). The way AEC professionals operate has changed due to technological improvements in computer graphics and CAD systems (Woksepp et al. 2006).

VDC strongly advocates for the use of models intelligible and assessable by all stakeholders involved in the construction process-whether an AEC professional, a user, a supplier, or a representative of various authorities. They are multidisciplinary models. Together with all the related participants, they represent the participants of the project: the architect, the engineer, the contractor, and the client. These are performance models since they predict the performance of projects, monitor key issues, and also depict projected and measured levels of performance congruent with the pre-defined project performance objectives (Kunz and Fischer, 2020)

Building Information Modelling
The architectural and functional characteristics of a building are represented digitally through Building Information Modelling (BIM) (Huahui, Deng, and Chang, 2019). It is a collaborative approach that includes the creation and sharing of digital data about a building across its lifetime (Salman, 2011). BIM is an advanced tool that facilitates virtual collaboration between owners, contractors, engineers, and architects. Geometry, materials, and performance characteristics are defined for a building in BIM models. The information can be used to develop a model that would simulate the building's performance under different conditions (Succar, 2009).

In recent times, BIM has been seen to be of great use to the construction industry. This is because it enhances project coordination by boosting efficiency and reducing errors that are developed, hence improving communication between AEC professionals during the whole process of a project. This eliminates miscommunications, which facilitates the decision-making process. Besides generating more accurate cost estimates, BIM models can be utilized to develop construction schedules that optimize the building process by reducing project timelines. (Eastman et al., 2008)

There is also proof that the ability of BIM to detect and solve problems in the building system, such as those in the mechanical, electrical, and plumbing areas, enhances the quality of projects. By being able to resolve such inefficiencies at the early design stages, the project team is able to greatly reduce revision and delay costs (Jin et al., 2019). The BIM model can also be used for generating construction details.

These models also help in reducing the incidences of errors during construction as shown by Johansson and Roupé, 2024. BIM also enables the management of facilities. It allows information regarding systems and components within the building. The data during maintenance locates such areas that may require replacements of repair within the system. BIM model will also be utilized for simulations in the amount of energy used by a building whereby through them, ways can be devised where energy usage may be minimized, (Firdaus Razali et al., 2019).

BIM is a powerful tool, changing the face of the construction industry. It is a critical tool for AEC professionals and other relevant stakeholders in that it enhances project coordination, reduces errors, and increases efficiency. The construction industry is increasingly adopting BIM as a standard practice as its implementation grows (EL Mounla et al., 2023).

Problem Statement
The integration of Virtual Design and Construction (VDC) and Building Information Modelling (BIM) has demonstrated substantial benefits in the construction industry, particularly in enhancing project sustainability and reducing waste. VDC integrated with BIM, enables the digital representation and coordination of building projects, streamlining processes from design to execution. This synergy helps minimize construction errors, optimize resource use, and foster collaboration between project stakeholders, leading to more sustainable outcomes in the short term (Adel, Cheng and Lei, 2022).

However, despite these evident advantages, there remains a gap in research concerning the long-term impacts of VDC-BIM integration on sustainability and energy efficiency. While existing studies have shown that these technologies can reduce project timelines, lower costs, and improve construction quality (Kunz and Fischer, 2012), their potential to sustain energy efficiency, particularly across the lifecycle of a building, has been less explored. Buildings account for a significant portion of global energy consumption and ensuring that they remain energy-efficient over time is crucial for achieving long-term sustainability goals (Zielinski Nguyen Ajslev and Elisabeth Ejstrup Nimb, 2022).

Research Questions
How can AEC professionals use data from BIM and VDC together to improve efficiency in the construction process?

Research Aim
To investigate ways of enhancing operational efficiency, this study will examine perceptions of building efficiency concerning the integration of Virtual Design and Construction (VDC) and Building Information Modelling (BIM). The findings aim to identify the effectiveness of VDC and BIM integration in improving performance and outcomes in construction projects.

Research Objective
To examine the efficiency of building processes through the integration of Virtual Design and Construction with Building Information Modelling.

Significance of the Study
Application research on the integration of VDC and BIM in the construction sector is now under progress, and many AEC scholars and construction professionals have given it a lot of attention recently. By examining published research and examining qualitative data, that will assist in understanding the long-term advantages that result from implementing BIM and VDC throughout the construction process. The results of this study can be used to develop theoretical frameworks that direct the effective integration of VDC and BIM in the Malaysian construction industry. Knowledge of relevant organizational and technological factors that affect the adoption and integration of both BIM and VDC will be relayed through this study.   Thus, it wouldhelp   with findings that inform the professions within AEC of the professionals who would further bring about the other relevant stakeholders with long Term   benefits. These professionals, in turn, assured by adopting   BIM   and VDC, would ensure development of knowledge not only in management but alsoin engineeri ng, as well as the guiding ideas to move forward further studies.

Research Gap
The research gap in BIM And VDC Integration, existing presently, is on the implementation strategies and impacted performance. Despite the increasing literature on benefits and efficiencies arising from BIM-VDC integrations, practical studies on the challenges, limitations, and facilitators of successful integrations in real building projects remain few. This can be attributed to the general lack of overall frameworks or guidelines that could systematically guide how BIM and VDC can be integrated in varied project contexts. Few studies have been conducted regarding the impacts of integrating BIM and VDC into project outcomes related to cost, time efficiency, quality enhancement, and sustainability. (Adel, Cheng and Lei, 2022)

Scope of the Study
The basis of the research will be the Malaysian construction industry. In this respect, a qualitative research approach will be carried out to find out how BIM and VDC are integrated and how their integration affects construction processes and project results over time. Data for the research will be collected by completing structured questionnaires with AEC professionals. Relevant literature regarding the adoption and integration processes of BIM and VDC will also be reviewed to develop the theoretical framework of the project. The findings from this study will be used to gain an enhanced understanding.

Literature Review
This research study elaborates on the broad framework of integration of VDC and BIM in the construction industry; thus, the current literature review chapter comprehensively examines the body of current literature to comprehend the intricate network of information on VDC and BIM integration. The learning interoperability of the digital components has become an essential element to learn as these technologies are continuously changing the sectors AEC. This paper will bring together a range of literature in highlighting different challenges related to the integration and long-term potential benefits of sustainability.

Strategies And Methodologies for Achieving Effective Integration
One of the key developments in modern construction techniques is the efficient incorporation of BIM and VDC technology into the building process. The aim of this section is to present ways and strategies on how to cooperate and achieve concurrence over difficulties inherent in integrating these innovative technologies. Previous research has pointed out that establishing standardized means and processes assists project stakeholders to successfully adapt (Adel, Cheng and Lei, 2022 Additionally, the estimation of building waste with the use of BIM in advance aids in waste estimations even before construction. It reduces costs and supports sustainability principles (Hasan, 2022). these approaches highlight how VDC and BIM could be utilized to achieve waste reduction and support sustainable construction processes. (EL Mounla *et al.*, 2023). The study of these solutions aims to provide realistic perspectives on shifting building processes to more eco-friendly and efficient construction.

Existing Strategies and Methodologies for Integration
The "**Collaborative BIM Approach**" engages in heavy emphasis on the incorporation of VDC technology with BIM to allow for coordination and collaboration of project stakeholders from the very start of the project lifecycle (Eastman *et al.*, 2008)
By combining time (4D) and cost (5D) dimensions into the BIM model, the "**4D/5D BIM Integration**" approach aims to improve project scheduling, cost estimation, and resource allocation (Çelik, 2020)
The "**VDC-BIM Integration Maturity Model**" creates the premise upon which to appraise integrating VDC technology with BIM in an organization, providing a suggested way in which this integration should be implemented and continuously improved (Chen *et al.*, 2023)
The "**Parametric Design and BIM Integration**" approach leverages the parametric modelling capabilities of VDC technology to help engineers and architects communicate and optimise designs (Adel, Cheng and Lei, 2022)
The "**Cloud-Based Collaboration Platform**" enhances real-time collaboration amongst project participants with information exchanges of the BIM model, which is made available to the different stakeholders using cloud-based hosting of the model (Johnny Wong *et al.*, 2014)
The objective of the "**BIM-GIS Integration**" strategy was to improve project visualisation, geographical analysis, and asset management skills by integrating GIS and BIM (Wang, Pan, and Luo, 2019).
Throughout the whole building process, these strategies for integration enable improved decision-making, coordination, and cooperation.

Evaluation of Different Approaches and Their Effectiveness
Many studies have explored the effectiveness of different methods of integrating VDC and BIM to improve construction processes and project results.
Lee et al. (2020) studied the possible benefits that can be derived from VDC using 5D BIM. In the case study, the construction process was simulated using a 3D model; time scheduling, 4D, cost estimation, and 5D data were used. The study explores how VDC and 5D BIM are applied in a commercial building project. Conclusions of the study revealed that the 5D model generated educational information key to the management of the design-construction process in all phases concerning scheduling and cost-related issues. The following can be identified from the literature review: six modelling processes and several aspects affecting the practicability of 5D BIM, including modelling tasks, interoperability, information output, and restrictions. Technical obstacles were reduced for clients in the VDC created with 5D BIM, and clients were more satisfied since perceptibility was closest to the actual construction results.

Another study by (Kim *et al.*, 2021) aimed to implement and integrate BIM and virtual reality in the design stage. It presents a three-tier, five-arena, fourteen-criterion, 29-metric BIM-based VR application evaluation framework. This application is performed with five different BIM-based virtual reality applications in an educational building design project. Results showed it to be complete, uniform, with indications for more when quantifying, mostly but flexibly. Yet, with deeper research, it promises more advancements to further phases of a project-for example, during the construction stage.

A Canadian general contractor explored how to implement digital construction through integrating stick-built construction with BIM and virtual design and construction (VDC) (Adel, Cheng, and Lei, 2022). The report has given a description of the exact responsibility of each party. It established a co-operative relationship which would enable quick adoption and expansion of new technologies for BIM and VDC. The questionnaire was designed with a background overview of the current trends, benefits, and problems regarding BIM and VDC, followed by questionnaires and interviews with professionals. The findings of this study are presented as a "Digital Construction Framework for the Future" which describes the functions and their relationships among the construction industry, institutions, government, and educational institutions. This framework will prove to be the most helpful tool to organizations with plans to implement BIM and VDC in their companies, and in future expansion and engagement with other Canadian companies and sites.

These studies identified that the combined use of BIM with virtual design and construction technologies has seen success in promoting the construction process, managing the complex tasks at hand, and adding value to clients. The issues, among others that this study pointed out are issues perceived in the 5D BIM models; problems of comprehensive project management based on a framework for assessment; BIM-based VR applications, and accountability in fostering collaboration in the use of BIM and VDC technology.

Cost-Reduction Techniques Using VDC and BIM Integration
The integration of VDC and BIM provides the AEC sector with an opportunity to drastically reduce the overall project costs throughout all processes of the project. These have been examined in detail by using a variety of techniques from earlier studies that show how the

integration of BIM and VDC results in overall cost savings at every phase of a project's life cycle.

Enhanced Accuracy and Cost Estimation
An effective cost-saving strategy is leveraging the combined strength of VDC and BIM in the creation of improved cost estimation (Eastman et al., 2008). With 5D BIM, professionals are able to develop a comprehensive and more accurate cost estimate early in the project life cycle because the cost data is integrated or incorporated with the 3D model.

Optimized Resource Allocation
The combination of VDC and BIM enables AEC professionals to maximise resource allocation by providing a comprehensive understanding of project objectives and constraints. (Salman, 2011). Better coordination and resource use are made possible by the visualisation of building sequences made possible by VDC's 4D scheduling capability. Research emphasises how crucial this tactic is for cutting waste, raising worker productivity, and eventually lowering project costs overall (Wang and Chen, 2023).

Clash Detection and Conflict Resolution
Conflict detection is a cost-saving approach further enhanced by integrating VDC and BIM to identify and resolve conflicts at the design and planning phase of a project. Clash detection reduces the possibility of rework costs due to design clashes occurring at the construction phase. Various studies conducted by Wang and Chen, (2023) and Lu, Lai and Tse, (2018) prove that such a proactive measure would lead to time and resource savings.

Improved Construction Sequencing and Planning
The integration of VDC and BIM will enable professionals to develop construction sequencing plans that are more accurate and efficient (Kunz and Fischer, 2020). VDC's 4D scheduling feature helps in visualizing project timelines, which helps in finding delays and bottlenecks. AEC professionals can minimize wasted time, enhance project productivity, and ultimately reduce costs by optimizing construction sequencing (Lu, Lai, and Tse, 2018).

Lifecycle Cost Analysis
The strategic incorporation of VDC and BIM data in the analysis of lifecycle cost enables cost savings. It is done by assessing the initial cost of the building and the operational and maintenance cost of the built environment. (Lu, Lai and Tse, 2018). Research by (Lu, Lai and Tse, 2018) that making decisions with considerations of lifespan cost has long-term financial benefits and encourages affordable and greener construction methods.

Performance Analysis and Continuous Tracking
Utilising VDC and BIM integration to implement continuous monitoring and performance analysis is a further cost-saving technique. (Zhang *et al.*, 2013). When paired with 3D models and schedule data, real-time data from construction operations allows experts to quickly spot plan deviations. This proactive strategy reduces the impact of possible cost overruns by enabling prompt modifications.

In summary, different methods of VDC and BIM for reducing the expenses of delivering an AEC project during a project are various. This is further supported by improved construction

sequencing, clash detection, lifetime cost analysis, enhanced cost estimation, resource optimisation, and continuous monitoring in strategies identified from recent research investigations. These solutions are not only effective and sustainable but also ensure the project will be less costly.

AEC Professionals' Integration of VDC and BIM to Increase Construction Process Efficiency
This integration of BIM and VDC in today's AEC sector has proved to be one of the key elements required in ensuring transparency throughout the construction process. General integration of BIM and VDC was able to develop effective cooperation, coordination, and efficiency throughout the life cycle of the project. Hence, basically, BIM is a collaborative working methodology based on digital models. With virtual design and construction, everything is done virtually to provide a cutting edge for improved results of the project. (Hui, 2018). Notably, the application of BIM occurs at various stages in building, hence indicating how significant it is since the very commencement of the construction process (Huahui, Deng and Chang, 2019).

By integrating BIM and VDC, one improves the general efficiency of the building process, project understanding, team collaboration, and data sharing. Thus, the power of BIM combined with VDC in immersive virtual reality while streaming construction methods has already been demonstrated in real-world applications, further increasing their effectiveness toward better project outcomes. (Rashidi *et al.*, 2022).

The Evolution of Integration of BIM and VDC
Building Information Modelling (BIM) and Virtual Design and Construction (VDC) have revolutionised the Architecture, Engineering and Construction (AEC) industry by offering sophisticated techniques for project planning, management and execution. The seamless integration of BIM and VDC is one innovative method that could increase overall construction efficiency.

Building Information Modelling (BIM) is a comprehensive process that involves developing and overseeing digital representations of a construction project's functional and physical elements (Eastman et al., 2008). For all of the key project stakeholders, this digital representation acts as a centralised, cooperative platform that facilitates efficient coordination and communication over the course of the project.

As a BIM extension, VDC extends the modelling process to include added elements. The combination of 4D scheduling with 5D cost estimation brings an added dynamic and economical dimension to the digital representation of these elements: time and cost, respectively (Salman, 2011). This multi-layered approach gives a more elaborative view of the project, which aids in the areas of planning and decision-making.

Combining the processes of BIM and VDC presents a construction process that works and enables the coordination participation for involved professionals and can offer total development of the understanding of a project that covers design, construction, and operational components (Succar, 2009). Besides providing accurate visualization, integration enables data-informed decision-making throughout the life cycle by relevant professions.

Collaboration is, therefore, an essential step towards the aim of process efficiency. Indeed, integration will enhance collaboration between various project stakeholders and enable better means of incorporating project management and execution (Zhang *et al.*, 2013 To this end, collaboration is a very important step toward the goal of efficiency in the building process. Understanding ongoing technology breakthroughs and improvements is necessary for the full realisation and active implementation of BIM and VDC. It has developed from simple integrations of 3D models into complex multi-dimensional representations of variously complicated elements such as quantity take-offs, collision detection, and building scheduling. Fischer and Kunz, 2020. This progressive development indicates how flexible the technologies are in terms of advancement and possible expansions within AEC (Kunz and Fischer, 2020)

It is, in this respect, regarded as one of the major breakthroughs in the AEC sector. The whole construction process has been very fast with digital representation, multi-dimensional models, and collaboration platforms. Understanding this growth creates the basis for an investigation into how AEC professionals can apply both BIM and VDC data to even further improve the process of construction.

Interoperability Issues in the Integration of BIM and VDC
Working over the operational and critical issues of interoperability will remain essential for effective integration of VDC and BIM systems. One of the critical issues that needs to be resolved is interoperability so that the integrated BIM and VDC systems function effectively. A review of the following literature has been underlined with a view to establish the need for effective communication of the various technologies continuously for optimal integration so as to optimise the potential of the combined data systems.

The interoperability problems arise because of the complexity and diversity of the BIM and VDC systems, usually built separately with the use of different standards and technological advancements. Researchers emphasize that to achieve interoperability, a uniform data protocol is necessary. Researchers (Eastman *et al.*, 2008; Succar, 2009) emphasize the need for a standardized data framework protocol in their works as a facilitator of the integration. Without standards, BIM and VDC cannot share and make inferences from this data, and the full advantages of collaboration and integration cannot be realized by the stakeholders.

According to the work of Eastman et al. 2008, the interoperability gap is not strictly technological but also socio organizational. The non-existence of procedures and standards in this regard leads to an unstructured information base, to which no player that may have an interest would know how to interact, and this aspect apart from ruling out real time cooperation, the result would not allow what will amount to be a useful application of integrated information for the perfection of the operations.

The interoperability issues, if addressed, would guarantee full benefits and leaps in BIM and VDC integration. This all-inclusive approach is supported by researchers (Wang and Chen, 2023) who advocate for a comprehensive approach that encompasses both technical and organizational aspects. (Wang and Chen, 2023) have identified the requirement for industry-wide standards and shared data platforms that allow for seamless sharing of data and stated that effective stakeholder collaboration with mutual understanding can ensure an environment of collaboration to encourage smooth integration.

Integration of BIM and VDC involves interoperability issues, which is an elaborate task. There are organisational and technological issues to be considered while integration is done. Therefore, addressing the crucial issues pertaining to the application of standardised data formats, protocols, and information exchange standards serves as a foundation for additional study and attention to industry practices in order to establish a shared framework for data interaction that can guarantee AEC professionals can use data from both BIM and VDC to improve construction performance.

Enhancing Collaboration and Communication
Architecture, engineering, and construction (AEC) professionals must work together and communicate effectively to integrate Building Information Modelling (BIM) with Virtual Design and Construction (VDC). This section demonstrates the way architects, engineers, and contractors can collaborate, thereby communicating the knowledge of different parties to utilize all types of project information from BIM and VDC data.

Successful utilization of BIM and VDC data calls for cooperation and communication. Researchers are repeatedly highlighting that a collaborative environment should be established to realize full benefits of these technologies. (Hartmann and Fischer, 2007). These collaborative efforts are vital for overcoming traditional practices within the construction industry, where different professionals operate independently.

Studies by (Hartmann and Fischer, 2007) show the shared platforms would facilitate real-time data availability, serving as a central hub in every activity while simultaneously providing several other stakeholders-employees, contractors, engineers, architects-with continuous, safe access to the same information. Due to continuous communication in real-time, any type of delays and errors in the entire process is totally avoided, increasing overall building construction efficiency.

Other key benefits of the collaborative platform include the potential of removing the barriers to communication (Hartmann and Fischer, 2007). Effective communication is central to effective collaboration on constructionprojects. The collaborative platform ensu res all project participants are on the same page through effective and unobstructed commu nication between the professions.

Furthermore, these collaboration systems have simulation and visualisation tools to assist in decision-making beside data exchange. Also, most importantly, it is dynamic. Hence, BIM and VDC experts are able to model various scenarios, predict and analyse the problem and collaborate to make effective decisions. (Hartmann and Fischer, 2007). This skill minimizes uncertainties and optimizes the use of resources, thus greatly helping to simplify the construction process.

Collaboration and communication are not only crucial during the execution phase but throughout all stages of the project life cycle. Collaboration is made possible by BIM and VDC, right at the very start of the project may even lead to considerably more precise scheduling and planning, according to research done by Hartmann and Fischer in 2007. This opens ways to a far more effective construction process where problems that could be serious are addressed before they arise.

Data Utilization for Improved Decision-Making
Virtual Design and Construction (VDC) and Building Information Modelling (BIM) combine to form a massive data bank that can alter decision-making processes besides changing the way construction industry projects are visualised. The vast collection of integrated data presented in this section can be used by AEC professionals in an effort to develop better decision-making and present state-of-the-art research findings.

Recently, the application of BIM and VDC data to decision-making has been the subject of scholars, who have advocated the use of analytical data analysis and visualization tools. (Zhang *et al.*, 2013). Using these tools to extract insightful information from the integrated data empowers professionals to make well-informed, data-driven decisions throughout the project lifecycle. This enables better analysis and making sense of large volumes of data, hence enhancing the overall efficacy and efficiency of project management by ensuring that decisions are based on accurate and complete information.

With BIM and VDC integrations that provide vast datasets, processing and analysis become feasible with data analytics applied by the AEC industry in the current period (Lu, Lai and Tse, 2018). From enabling professionals to derive valuable information by identifying a set of meaningful data to make proper data-driven decisions in every project life cycle phase. Analysis of the data will show trends, patterns, and correlation-based analysis in the data and will educate the professionals on a number of project-related topics. For instance, the study could look at past project data to assist experts in finding recurring patterns that could improve schedule optimization, risk mitigation techniques, and resource management.

Visualization tools, on the other hand, play a crucial role in translating complex data into easily understandable and actionable models (Zhang *et al.*, 2013). Graphical presentation of data exposes professionals to the project in detail; hence, they make decisions faster. This includes three-dimensional visualization such as construction sequencing simulations and clash detection, which help the experts in locating the potential conflict regions and optimizing the construction process before actualization.

Judgments using real-time data obtained from BIM and VDC would, therefore, be even more dynamic. Since experts in AEC work with updated information instead of static data, the ability to change becomes smoother, instant, and is shared at once with all parties concerned. The projects can, therefore, react faster in case of unprepared barriers or tides of change in project demands.

Research Methodology
Any research publication without a research methodology chapter is never complete; it gives the proper framework for conducting and evaluating the study. This will contain a proper explanation of strategy, plan, and procedure in attaining the goal of the study.

Introduction
The research design for this study is formulated to allow an in-depth analysis of how BIM and VDC are integrated within the construction industry. The qualitative interview method, which will be applied to this study, is useful for the in-depth analysis of subtle yet highly subjective opinions of the stakeholders themselves who are actively involved in VDC and BIM projects.

The qualitative interview approach is employed due to its capacity to extract rich and detailed information from responses by using open-ended questions (Mayan, 2016). an in-depth information on the details and experience in VDC and BIM integration is required, and such a data collection plan allows the participants to make a remark on their experiences, attitudes, and opinions. The construction business is dynamic, hence qualitative interviews have to be flexible for generating reliable data.

Participant-Centric Approach: A distinct characteristic of the qualitative interview approach is its participant-centric nature (Mayan, 2016) The rationale behind using the methodology is that it will create direct interaction with AEC professionals who are involved, during relevant stages, with VDCs and BIM projects. This suits the study objective, which deals with collecting first-hand accounts of experiences to create an accurate and detailed explanation of the phenomenon. Expert participation by the professions that relate to AEC, both from within and outside, such as architects, engineers, project managers, and designers, among others, guarantees in-depth investigation and exclusion of limited view to offer insights into the process of integration (Mayan, 2016).

Justification for Selecting Malaysia as the Research Location
Malaysia has been chosen as the base for this study in understanding the adoption of BIM and VDC within the AEC sector because of a number of strategic reasons which make it of high value and relevance. The study of Malaysia regarding this subject matter is important for various key reasons:

Diverse AEC landscape. The AEC sector in Malaysia is diverse and rich, encompassing residential, commercial, and infrastructural construction. Nevertheless, the diverse nature of Malaysian construction projects provides a solid foundation for researching the use of BIM and VDC across several industries and, as a result, the potential and problems associated with integration. (Kamal *et al.*, 2012).

Economic growth and infrastructure projects. Due to huge expenditures within a wide array of infrastructure projects, Malaysia has achieved tremendous economic growth through time. Additionally, the use of BIM and VDC is gradually turning out to be more vital in the efficient management of complicated construction projects. It is evident that just by looking at how these technologies are being put to use in the advancement of sustainable development-one may know quite a deal about the role both BIM and VDC play to attain this Malaysian infrastructure development. (Kamal *et al.*, 2012).

Technological Adoption Trends. In many areas, Malaysia has shown that it is willing to embrace technological innovation. A careful review of Malaysia's BIM and VDC implementation reveals a nation's readiness to adopt cutting-edge technology in the AEC sector. (Kamal *et al.*, 2012).

Multi-cultural workforce. This extended and diversified workforce of the AEC sector in Malaysia is represented by both domestic and foreign experts. Such a multicultural setting will give a good overview of how different practitioners deal with obstacles and facilitators while integrating BIM and VDC into the study of engineering, architecture, interior design, and project management (Kamal *et al.*, 2012).

Transferability of Findings. The result from this Malaysian study could be used as a case by other developing economies with similar characteristics and problems found in their respective AEC sectors. In sites where similar technological, cultural, and economic contexts

are observed, drivers to integrate BIM/VDC would, to a better level, be contextualized by knowledge, experience, lessons, and insight derived from Malaysia. (Kamal *et al.*, 2012). Ultimately, Malaysia was chosen where the research objective of the study was to provide practically applicable yet rigorously scholarly insights into emergent dynamics of BIM and VDC integrations into AEC. The special features of the AEC environment in Malaysia make it a suitable and instructive context in which the challenges and dividends associated with the actual application of these game-changing technologies can be usefully explored.

Defining Research Questions
To understand the various nuances in integrating VDC and BIM within the AEC sector, research questions have to be formulated. The same will guide our inquiry into the whys, challenges, and experiences that AEC professionals go through as they try to seamlessly integrate new technologies into the processes of their work.

The research questions have been cautiously selected, taking into consideration the varied perspectives of key players in the AEC industry, such as engineers, architects, interior designers, and project managers, in regard to the diverse nature of BIM and VDC integration. Each question is elaborated on with the aim of analysing both the technical and human aspects of the integration process.

Table III.1
Summary of Research Methods, Objectives and Samples.

No	Objectives	Research Questions	Research Method	Research Domain	Selection of Sample
1.	To examine building process efficiency by integration of Virtual Design and Construction with Building Information Modelling	How can AEC professionals use data from BIM and VDC together to improve efficiency in the construction process?	Qualitative Interview	Construction process optimization Project Management Collaborative workflows	Professional Interview Respondents: 30 AEC professionals with industry experience in VDC and BIM integration

Sources And Methods of Collecting Primary Data
This section discusses the sources and techniques used in gathering the primary data related to studies on integrating BIM and VDC technology. Primary sources will include AEC specialists: architects, engineers, interior designers, and project managers who have participated actively in the integration process.

Interviews
In-depth interviews are the most effective strategy because they provide open-ended enquiries that elicit information about building process efficiency and construction costs. Making informed permission, privacy, and confidentiality a top priority guarantees polite and reliable data collecting.

Justification of Selection of Interviewees

The selection of respondents is a very crucial initial step in ensuring the quality and applicability of data gathered in this study. The targeted interviewers are professionals in the AEC industry, consisting of architects, engineers, interior designers, and project managers. This diversity ensures comprehensive representation of views and experiences related to the integration of BIM with VDC technologies. Purposeful sampling will seek out those who have experienced firsthand the implementation of such technologies and possess valuable insights into the complex relationships between building process efficiency and construction costs.

A popular method in qualitative research, snowball sampling enables the researcher to choose participants who may offer the most insightful and relevant information on the subject while additionally allowing them to find more participants from their networks (Huyler et al. 2019). For this study, professionals with direct experience in both VDC and BIM technologies will be selected. With their practical experience, they will be able to give elaborate explanations of the benefits, difficulties, and results of incorporating these technologies into real building projects. This approach is the best since it ensures that the study captures the views of those individuals who best understand the subject, thereby enhancing the depth and richness of the data (Huyler et al. 2019)

The architecture, engineering, and construction (AEC) industry is also renowned for its collaborative nature, in which many specialists collaborate to successfully complete projects (Mohammad S. Al-Mohammad, Ahmad Tarmizi Haron and Rahimi A. Rahman, 2023). The study can more accurately depict the interdependent processes, and interconnected workflows present in VDC and BIM integration by choosing participants from a variety of specialities.

I reached saturation in the process of data collection when new data no longer contributed to adding themes or insights to the research questions. Saturation was evident because similar themes kept emerging with consistency across all the responses of the participants and elaborated on already noted themes instead of offering new insights or fresh data. This is usually accepted as a natural boundary, especially in qualitative research, which seeks intensive understanding rather than extensive variation (Braun *et al.*, 2021). By achieving saturation in this way, it is confirmed that adequate depth and scope were attained, bolstering the validity of the data analysis and guaranteeing that the results accurately represent the experiences and opinions of the participants. (Mayan, 2016).

Additionally, saturation is a very subjective idea which may variously be defined and measured by different studies; that may be the reason for the variation in depth in similar studies. Transparency of the strategy of data collection may be perceived when saturation is presented as one of the methodological limitations. It also brings into light that generalization of findings must be in regard to limits put by the saturation level established for the study. (Braun *et al.*, 2021).

Interview Procedure

This section explains the methodology of research used for consolidating a comprehensive understanding of VDC technology integration and BIM incorporation. A link of the interview questions was provided through the efficiency and accessibility of the Google Form, with open-ended, structured interview questions. On average, each respondent discussed his or

her experience and thoughts for 45 minutes. The first respondents were then invited to further pass on the form within their professional networks, increasing the pool of respondents.

Accordingly, the interview conducted in this study was designed to be rich and with full detail for the researcher to attain a deep comprehension of how both VDC and BIM can be integrated within an AEC context. In general, the interview method, characterized as one with open-ended questions, gives the best methods which allow in-depth exploration into what happens regarding respondents' experiences (Virginia Braun et al. 2023). This is especially helpful to get detailed information on complex processes, such as VDC and BIM integration, by allowing the respondents to provide not only factual data but also their subjective interpretation of the facts.

An interview protocol was drafted in advance of collecting the data to ensure uniformity and accuracy. The protocol was designed to show the procedures under which the interviews were conducted, the sequence of the questions, instructions to respondents, and follow-up inquiries. (Kallio *et al.*, 2016).

These interviews were conducted with the help of Google Forms for their easy accessibility and user-friendly interface. The online platform was chosen because it allowed greater outreach for participants easily and effectively, especially in this post-pandemic world where working from home and virtual communication have become common (Braun et al., 2021). Google Forms provided a reliable avenue for data collection, as responses were stored automatically and securely, reducing any chance of losing data or mismanaging them. The choice to use an online tool also indicated sensitivity to the fact that AEC professionals faced a lot of time pressure and could therefore complete this interview at times that suited them best.

Additionally, the strategy of inviting early respondents to spread the link to the interview in their network contributed to the sample size. What is described here represents a version of snowball sampling, which has been very effective in studies targeting special professions, whereby one makes use of personal and professional networks to get in touch with subjects hardly approachable otherwise (Braun et al., 2021). This method also had the effect of increasing the number of respondents and providing a diversified pool of participants, thus enriching the findings.

Interview Questions, Potential Insights and Aim
Section 1.
Introduction
What is your primary profession within the Architecture, Engineering and Construction (AEC) industry?

Section 2
Enhancing Building Process Efficiency Through Vdc and Bim Data Integration
1.   1. Give some examples of where and how VDC and BIM integration to the building process expedited it, every instance making large productivity enhancement possible in this field,

covering everything from planning through design and construction. What do you consider as the leading reasons for the success?

2. 2. In general, how would real-time access to data through BIM and VDC influence decisions among AEC professionals? Have you worked out choices to which you feel access to real-time data contributed?

3. 3. During the integration of VDC and BIM, have the ways of collaboration and communication among project stakeholders changed? Provide relevant examples of how this cooperation enhances general effectiveness in the process of building.

4. What, in your opinion, is the most crucial issue for an AEC professional looking to maximize BIM and VDC data utilization for enhancing process efficiency?

5. 5. What, in your view, are the still-untapped opportunities for AEC professionals to leverage data from BIM and VDC in service of making the building process more productive in the future? Provide any relevant examples of new developments in trends or technology that may help create this change.

In order to gain a thorough grasp of the advantages, difficulties, and revolutionary possibilities of combining Virtual Design and Construction (VDC) and Building Information Modelling (BIM) in the Architecture, Engineering, and Construction (AEC) sector, the research will attempt to answer these questions. A comprehensive examination and insights into this developing sector will be facilitated by the range of viewpoints and experiences obtained from respondents in various positions and projects.

Method of Data Analysis

This section describes the methodical process that was used to interpret the information obtained from interviews on the combination of Building Information Modelling (BIM) and Virtual Design and Construction (VDC) technologies. NVivo software, a potent qualitative data analysis tool, will be used to process and comprehensively evaluate the interview data. The first step is to incorporate the interview responses into the NVivo platform, which aids in data organisation and classification for a thorough comprehension of the combination of Building Information Modelling (BIM) and Virtual Design and Construction (VDC) technologies.

Thematic analysis is used for the identification of recurrent themes, pertinent topics, and variation in the data collected. In conducting this analysis, the material will be coded, with labels applied to the primary concepts represented in the text passages. These codes are to be organized in an evolving system of overarching themes, which then facilitates the identification of the trends and variations in the answers from participants.

Using NVivo for analysing the connections of various themes within the research makes it even more in-depth and complex. Statements and visualizations from the software will be used in showing relationships, trends, and anomalies that provide a better understanding of challenges, attitudes, and effectiveness related to VDC and BIM integration.

Furthermore, participant validation will be conducted to enhance the reliability of the results. The participants are requested to provide real-life examples to validate the themes identified and to ensure that the interpretations are consistent with their original responses and experiences.

This qualitative data analysis method is meant to provide key insights into the various aspects of VDC and BIM integration in Malaysia's AEC industry through a holistic and systematic investigation.

Research Limitations

In retrospect, there are some limitations to the study that engaged a bearing on the extent and applicability of the findings. Due to time and financial constraints, the survey had to sample a limited number of AEC experts. This did have an effect on the general applicability of the findings to the entire population of AEC professionals in Malaysia's building industry, although it was unavoidable under the circumstances. Despite efforts to guarantee diverse representation, sample size limits must be considered when interpreting the results.

Furthermore, the study's focus on the integration of Building Information Modelling (BIM) and Virtual Design and Construction (VDC) meant that not all possible factors that might have influenced the adoption and effectiveness of such technologies in the construction process could be studied because the research narrowed its scope to the adoption of VDC and BIM. More contextual factors might have influenced the findings, which were not exactly captured during our study. These limitations have to be put into consideration if the findings of the study and their broader implications are to be truly understood.

The unwillingness of participants to participate in extensive interviews due to time constraints created a challenge. Despite efforts to streamline the interview and minimise participant pressure, there was still an element of reluctance. Although this limitation was partly overcome through encouragement of participation by the participants themselves and clarity in communication, it nonetheless impacted the scope and depth of the insights gained. Furthermore, privacy concerns are identified as an essential element during the study. Though people showed eagerness regarding sharing their view, the participants were not willing to share particular information for the purpose of the investigation. The outcome of such scenarios has occurred due to their urge over maintaining professional identity along with privacy concern. In this context, the research study has failed to attribute the quote to a particular individual and provide detailed participant profile. Notwithstanding these restrictions in privacy, every precaution was taken to ensure participant anonymity when the results were shared. These privacy concerns need to be understood and addressed as part of understanding the limits of the study. It also points to the importance of a balance between openness and secrecy in the dissemination of research findings.

Conclusion

The methodology adopted in this study contributes significantly to the understanding and exploration of the integration of Virtual Design and Construction (VDC) and Building Information Modelling (BIM) in the Architecture, Engineering, and Construction (AEC) industry. Through qualitative interviews with industry professionals, this research provides a deep, contextually rich understanding of the real-world applications, challenges, and potential of these technologies. The constructivist paradigm, combined with a purposive

sampling strategy, ensures that the research captures the diverse perspectives of professionals who have firsthand experience with VDC and BIM in practice. This study's methodology is not only robust but also aligns well with the dynamic and complex nature of technological integration in construction.

This research contributes to academic knowledge by offering insights into how VDC and BIM can influence construction processes, particularly concerning cost reduction and process efficiency. The qualitative interview approach allowed for the collection of nuanced, detailed experiences from professionals across different sectors of the AEC industry. Such firsthand accounts offer valuable contributions to the academic literature by highlighting how the integration of these technologies impacts real-world project outcomes. Furthermore, this study's focus on the practical applications of VDC and BIM bridges the gap between theoretical models of technology integration and the realities of implementation, offering an empirical base for future research. The findings from this research will help shape future studies aimed at understanding how digital construction technologies can further revolutionize the industry.

From a methodological perspective, this research demonstrates the efficacy of using qualitative interviews to explore complex and evolving phenomena like the integration of VDC and BIM. The structured yet flexible nature of qualitative interviews enabled the study to capture both general trends and specific, detailed insights from participants. The use of purposive sampling ensures that the selected participants had direct, relevant experience with the integration of these technologies, which is critical in maintaining the reliability and validity of the findings. Additionally, the data collection tools, including open-ended questions distributed via Google Forms, streamlined the process, making participation accessible to a broader network of professionals. This approach demonstrates how digital tools can effectively complement traditional qualitative methods in the age of remote work and technological integration.

The findings from this study hold substantial implications for the AEC industry, particularly in enhancing the adoption and integration of VDC and BIM technologies. By identifying real-world examples of cost reduction, process efficiency improvements, and challenges faced during integration, this research provides practical insights for industry professionals. These insights will assist companies looking to adopt VDC and BIM by offering proven strategies for overcoming barriers and capitalizing on the benefits of these technologies. Furthermore, the study's focus on real-time data accessibility, stakeholder collaboration, and decision-making provides a roadmap for how industry professionals can better leverage digital tools to optimize construction processes. The findings may also guide policymakers and industry leaders in developing guidelines and best practices to encourage widespread adoption of VDC and BIM in the industry.

In conclusion, the research methodology employed in this study sets a strong foundation for future academic exploration and industry innovation. By focusing on qualitative insights from experienced professionals, the study not only expands academic knowledge but also offers practical applications that can enhance the efficiency and cost-effectiveness of construction projects. The use of qualitative interviews as the primary strategy of inquiry proves to be an effective method for exploring complex, technology-driven subjects, providing a model for

future research in both academia and industry. Future studies could build on this work by incorporating quantitative data or expanding the sample size to further validate the findings and explore additional dimensions of VDC and BIM integration in construction projects.

Data Analysis and Results

This chapter provides a comprehensive thematic analysis of the qualitative data collected from professionals in the Architecture, Engineering, and Construction (AEC) industry on the integration of Virtual Design and Construction with Building Information Modelling, their roles and experiences, implementation strategies, encountered problems, cost reduction and efficiency improvement strategies, as well as future opportunities and emerging technologies. The thematic analysis will answer the research questions and objectives by providing insights about how VDC and BIM integration can help enhance construction efficiency and cut costs.

Professional Roles and Experience In VDC/BIM

The data reveals very diverse roles are involved in the execution of VDC/BIM projects; this varies from BIM managers and project managers to architects and engineers. Each role presumes a set of tasks and possible viewpoints which are necessary to effective VDC/BIM implementation

Roles in Projects

BIM Manager: Responsible for managing digital models and ensuring the accuracy of data to support effective decision-making and coordination.

Project Manager: Overall management of a project, applying VDC tools in areas that pertain to project visualization, scheduling, and resource allocation.

Architect: Involved in designing and optimizing building processes with BIM, perhaps with an additional emphasis on collaboration in VDC/BIM projects.

Engineer: The technical roles in construction, leading the optimization process toward construction methods and efficiency gains through VDC/BIM.

All these roles represent that VDC and BIM are widely practiced across most functions in the AEC industry; therefore, specialized skills and knowledge are required to implement and manage these technologies effectively.

Years of Experience

The participants were fairly experienced, with a range of 12 to 24 years of experience, which means they had a high level of expertise and are well acquainted with practices that are common in the industry. The long years of experience form a basis for effective uptake and utilization of VDC/BIM technologies. Such as the senior engineer who underlined, at 18 years of experience, the fact that VDC is an adopted mean of increasing project efficiency. Another is the chief architect, a 24-year-experienced architect, who said that only joint efforts can lead to the result.

Specific Projects Using VDC/BIM

Participants described a number of projects with great depth where VDC/BIM was utilised – these ranged in scale from massive infrastructure development to highly detailed building optimization.

Bridge Construction: An engineer shared the experience of a bridge construction project and how the application of VDC and BIM tools helped in providing clearer planning and coordination, therefore completing a project successfully.

Building Optimization: An architect explained the application of BIM in developing multi-dimensional digital models that have simplified the coordination between various disciplines and minimized the errors in construction.

In these examples, it can be seen how VDC and BIM can be used to optimize project planning, coordination, and implementation that correlates with the research objectives to explore perceptions on cost reduction and the efficiency of building processes.

Project Implementation and Objectives
Implementation Strategies
The purpose of integrating VDC and BIM is to increase the level of coordination, improve the project's deliverables, and smooth the workflow. Respondents explained different ways of applying the strategies that further helped in implementing VDC/BIM integration.

Improved Collaboration: VDC/BIM integration improves the collaboration between the stakeholders and eases communication and coordination. For instance, one of the project managers applied the use of VDC tools to improve visualization and enhance coordination in projects. This showed the hands-on application in complex projects.

Quick Decision-Making and Planning: Real-time data availability makes it possible to make better decisions and plans. One engineer noted it that the data was available seamlessly to enable real-time adjustments, thus enhancing the project efficiency.

Process Optimization: Construction processes can be optimized through VDC/BIM tools, leading to time reduction and increased productivity. One architect described the collaboration of all processes and centralized decision-making that was possible through VDC and how it directly results in the reduction of lead time for any project.

Objectives and Outcomes
Common goals of VDC/BIM integration in both cases were improvement of project outcomes and increasing efficiency while decreasing costs. Interview participants shared how it was achieved in two case studies:
Increasing Efficiency: BIM/VDC enabled better scheduling and resource allocation, hence better project performance. A project manager highlighted the use of 4D BIM, which integrates the time dimension with 3D models, allowing for better scheduling and resource allocation.
Cost Reduction: The participants emphasized that the correct estimation and allocation of resources are directly linked to cost reduction of projects. An engineer described how 3D BIM models supported better estimation of costs, which in turn reduced errors during the construction stage.
Sustainability: VDC/BIM integration also supports sustainable building practice due to better-informed decisions regarding materials and methods of construction. One architect

mentioned using BIM to simulate various building scenarios with the aim of achieving the best possible sustainable construction.

These aims and objectives demonstrate how VDC and BIM can enhance project planning, coordination, and execution towards evaluating the perceptions of cost reduction and examining building process efficiency.

Challenges In VDC/BIM Integration
VDC has been regarded as one of the excellent technology strategies for improving construction project outcomes, reducing construction costs, and minimizing project cycle times with improvement in quality. However, the utilization of VDC technology is faced by a number of challenges and limitations in Malaysia.

Technological Literacy
A major challenge in the complete integration of VDC/BIM is the difference in technological literacy among the professionals. Training and professional development should be a continuous process to cope with the changes in technologies.
Lack of Training: Most participants felt that there was a steady necessity for further training so that the entire team will be well versed in the most up-to-date tools and practices. A BIM manager spoke about the challenge of keeping all staff up to date with new technologies and ensuring similar practice across projects. This is yet another barrier.
Resistance to Change in Technology: With the notion held that VDC/BIM technology is associated with a high cost and will disrupt normal processes, organizations are not ready to adopt the technology. Proving the long-term value and return on investment through the use of the technology can minimize the resistance.

Data Integration
These challenges include issues of data integration and interoperability. Hence, there is a need to develop standards in data exchange:
Standardized Processes and Open Data Formats: Need to establish how to best integrate the data with each other. For example, an engineer referred that the challenge is that the interchange of data needs to be seamless since companies may own different software platforms and came out with the need to standardize processes.
Interoperability: Effective integration of VDC/BIM across various software platforms. All the participants emphasized that open data formats should be used for better data exchange and interoperability.

Organizational Resistance
Organizational resistance towards new technology remains a challenge to VDC/BIM integration. Participants reported that some organizations resisted VDC/BIM integration because they perceived it to be costly and would cause a workflow disruption.
To overcome the organizational resistance, one has to demonstrate long-term value and ROI of VDC/BIM. One project manager described how he had sold the potential value of integrating VDC/BIM to the stakeholders, making them jump on the bandwagon.

Other than the organizational culture, VDC/BIM technology use is associated with the work culture factor. Greater importance is given by the respondents of the study to the need for work culture change by adopting a new technological approach and continual improvement.

Training and awareness programs can be conducted in order to encourage a positive attitude toward VDC/BIM integration.

These issues emphasize the need for continued effort in addressing the issues related to technological literacy, training, organizational resistance, and data integration—both questions and objectives.

Methods For Improving Efficiency With VDC/BIM

The participants cited this as a key agenda in the integration of VDC/BIM. Optimization of construction processes that was realized from this was identified as one of the means through which efficiency was achieved, real-time data access, and enhancement of collaborations.

Process Optimization: VDC/BIM allows optimization of construction processes; the reduction of lead time and improvement of efficiency. An architect explained that decisions were assimilated and centralized, hence with the help of VDC, able to reduce the project lead times.

Real-Time Data Access: Good decisions and planning were facilitated by real-time data availability. Participants remarked that this was made possible because of the smooth availability of data, where real-time adjustments could be made for better project efficiency.

Improved Collaboration: VDC/BIM integration allows seamless collaboration between all stakeholders, which allows clear communication and coordination. They further commented that, due to the VDC/BIM integration, improved visualization together with shareable data resulted in proper collaboration among the stakeholders and hence an increased speed in project implementation.

Data Sharing Among Stakeholders: The feature allows seamless sharing of data among the stakeholders of the projects. The real-time sharing of data helps individuals make changes swiftly and plan accordingly. One participant made a statement about how the real-time availability of data will assist in reducing lead time by not causing unnecessary delays.

VDC/BIM Integration for Risk Management: The possible issues are identified with the help of detailed simulations and 3D models, which in turn adopt measures at an early stage of the project. Therefore, overall project efficiency is increased through cost minimization on rework as a result of improvement.

Visualization and Simulation: Participants shared that 3D models and detailed simulations are key to increasing efficiency. The models, according to the participants, helped them visualize more effectively, reduce risks, and make faster decisions that were efficient in supporting the construction process. Better collaborative work and communication through the models of VDC/BIM also emerged as factors in improving efficiency.

Future Trends and Opportunities

Looking forward, participants identified several untapped opportunities and emerging technologies that could further enhance VDC/BIM integration. These include green building practices, augmented reality (AR), and artificial intelligence (AI).

Green Building Practices

Sustainable Design: One of the participants was of the opinion that green buildings may be the way forward, and with this view, it was proposed that in a VDC/BIM environment, sustainable building scenarios can be modelled and simulated so that energy-efficient and

greenly constructed buildings come through. For example, if the design is made such that it favours natural airflow and light that reduce artificial heating or cooling loads, then it may serve the purpose of efficiency and cost reduction.

Resource Optimization: VDC/BIM also works towards resource optimization with accurate estimations of resources and minimization of material waste. This in turn leads to more sustainability in construction practices, complementing global sustainability goals.

Augmented Reality (AR) And Artificial Intelligence (AI)
Augmented Reality (AR): AR can significantly improve on-site visualization and decision-making. Integrating AR with VDC/BIM allows stakeholders to visualize construction elements in real-time, leading to better planning and execution. A participant highlighted that AR could alter the future of construction by providing immersive visualization experiences.
Artificial Intelligence (AI): AI offers insights for optimizing construction processes. For instance, AI can analyse large datasets to identify patterns and recommend efficient construction methods. Participants noted that AI integration with VDC/BIM could lead to smarter, data-driven decisions that enhance project efficiency and reduce costs.

Modular Construction
Prefabrication: VDC includes modular construction techniques that need to be effectively implemented while integrating. These help in overcoming the limitations of design and architecture by allowing the prefabrication of components of the building, which can later be assembled at the site to reduce time and cost incurred for construction.

Construction Sequencing: This forms another area where professionals could use more data from VDC/BIM integration to ensure that the resource allocation, scheduling, and sequencing of construction are accurate. The participants highlighted a need for detailed modelling to facilitate effective planning and sequencing of construction activities.
These insights highlight the potential for VDC/BIM integration to drive future advancements in the construction industry, aligning with the research objectives of exploring future opportunities and emerging technologies.

Conclusion
The thematic analysis of AEC professionals' qualitative data manifests an in-depth insight into roles and experiences in VDC/BIM projects, challenges encountered, and future opportunities of increasing efficiency in the building process while at the same time reducing costs. Addressing such highlighted challenges and exploiting new technologies is bound to see the construction industry achieve even greater collaboration, efficiency, and sustainability in delivering projects.

This means that all the time invested in continuous training and professional development, the standardization of processes, open data formats, and those newly emerged technologies such as AR and AI are worthwhile. This information will be very useful to professionals and organizations in the AEC sector that seek to adopt VDC and BIM technologies for their projects. Accepting those strategies would enable AEC to ensure that barriers to VDC/BIM integration can be effectively overcome in carrying forward the full power of these transformative technologies.

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