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AWARENESS AND PERCEPTION OF QUANTITY SURVEYORS TOWARD THE SMART CONSTRUCTION CONCEPTS

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Abstract: The construction industry is undergoing a transformative phase due to the integration of modern technologies such as Building Information Modeling (BIM), the Internet of Things (IoT), Big Data, Machine Learning, and Blockchain. Quantity surveyors, as pivotal figures in construction projects, must adapt to these advancements. Therefore, the research aimed to determine the perception and impact of new smart concepts and technological trends on quantity surveying professionals. Accordingly, the research adopts a mixed approach. The data was collected through semi-structured interviews and questionnaires. Manual content analysis and the Relative Important Index (RII) were used to analyse the collected data. The findings demonstrate that all identified smart construction concepts significantly influence the quantity surveying profession, with BIM exerting the most substantial impact. Further, the study emphasises the urgency for quantity surveying professionals to upgrade their knowledge and skills to remain relevant in this technologically advancing landscape. Moreover, the research recommended that industry professionals, construction organisations, and academia facilitate this knowledge enhancement through Continuous Professional Development (CPD) workshops, webinars, specialized training sessions, and formal education programs to stay abreast of these modern trends and technologies. Subsequently, this research serves as a valuable guide for stakeholders, encouraging proactive steps towards integrating modern technology into the traditional domain of quantity surveying.

Keywords: Awareness, Knowledge, *Impact, Quantity Surveying, Smart concepts*

1. Introduction

Quantity surveying is a prominent profession in the construction industry that is associated with large-scale construction procurement processes, cost planning, cost management, asset management, feasibility studies, and contract administration (Said et al., 2010). Further, various definitions of a quantity surveyor have been provided by different authorities. Accordingly, CIQS (2020) defines a professional quantity surveyor as a professional who has comprehensive knowledge of construction and construction methods and the laws relating to construction projects and accounting to provide cost and financial advice. Ashworth et al., (2013) have defined a professional quantity surveyor as a construction industry professional who "ensures that the resources of the construction industry are utilised to the best advantages of society by providing, inter alia, the financial management for projects and cost consultancy services to the client and designer during the whole construction process." Badu and Amoah (2004) emphasised that the client's quantity surveyor responsibilities include preparing Bills of Quantities (BOQ), cost planning during the design stage, analysing and examining tenders, pricing quantities, value engineering, and negotiating contracts and rates. Additionally, the author mentioned the contractor's responsibilities, such as the preparation of BOQs for sub-contracts and assisting the contractor with scheduling plans. Ashworth et al., (2013) have described the traditional quantity surveyor as possessing knowledge of procurement and tender procedures, contract administration and documentation, cost planning and management, preliminary estimation methods, cost and cash flow forecasting, financial reporting, interim payments, project management, financial accounting, dispute resolution and arbitration, cost advising, and tender evaluation. Thus, the role of quantity surveyors remains pivotal in the construction industry.

The construction industry is undergoing rapid evolution, and it is imperative for modern professions to adapt in tandem with these changes (RICS, 2020). As expressed by the Canadian Prime Minister at the World Economic Forum, the pace of change is unprecedented, and industries are transforming at an unprecedented rate (RICS, 2020). Consequently, the construction industry and the role of quantity surveyors are evolving due to several critical factors. Ashworth et al. (2013) outline that the future of the quantity surveying profession is being shaped by factors such as client requirements, advancements in information and communication technologies, and the research and

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sustainability agenda. Smart systems and concepts employed in the industry aim to enhance the effectiveness and efficiency of construction projects. Moreover, Steve Appleby highlighted that smart systems that combine project data with operational systems are beginning to inform business decisions, leading to greater efficiencies, by linking systems it is possible to achieve value greater than the sum of their parts (AECOM, 2014). Further, the evolution of the IT sector has introduced new technologies to the modern world that can shape and evolve the construction industry more effectively and efficiently. According to Seidu et al. (2019), smart technologies such as BIM, Big Data, Machine Learning, Blockchain, and IoT possess the potential to enable quantity surveyors to investigate deeper into complex aspects of construction cost management procedures and provide innovative solutions in a highly effective and efficient manner. Hence, it is evident that the quantity surveying profession must undergo upgrades in sync with the construction industry's evolution, embracing new smart concepts and technological trends to remain effective and relevant.

BIM stands out as one of the prominent concepts and emerging technologies that shaped the future of the construction industry and quantity surveying profession. Autodesk (2020) defined BIM as a process that begins with the creation of an intelligent 3D model and enables document management, coordination, and simulation throughout the entire life cycle of a project, covering stages from planning and design to construction, operation, and maintenance. Zhang et al. (2015) argue that utilizing algorithms for tender evaluation based on large volumes of data can improve the process significantly. Further, Big Data can be described as a large volume of complex data that consists of greater variety and arrives at higher velocities (Oracle Corporation, 2021). Machine Learning can be recognised as a technological method that can be used to cluster, predict, and classify tasks after Big Data has been analysed (Hussain et al., 2018). Rodrigo et al. (2018) explain blockchain technology as a decentralised distributed ledger system spreading across several locations without intermediaries, leading to ensuring trust. Perera et al., (2021) argue that this decentralised distributed ledger system has great potential to solve contract-related issues in the construction industry, particularly in digitizing the construction procurement process. Furthermore, IoT has the potential to save 22%-29% of the total construction costs by reducing human errors and communication costs, and increasing the efficiency of reporting, which can lead to cyber-physical construction, known as Construction 4.0, considered the next revolution of the construction industry (Ghosh et al., 2020).

However, Seidu et al. (2020) affirmed that a lack of awareness among construction professionals, particularly quantity surveyors, regarding new smart concepts and technological trends such as Big Data, AI, and Machine Learning techniques. This limited awareness has hindered the industry's ability to keep pace with advancements seen in other industries. Indeed, to safeguard the future relevance of quantity surveyors, it is imperative to prioritize enhancing their knowledge and perception of smart technologies. To address this issue, it is necessary to evaluate the existing perceptions of quantity surveyors concerning these smart concepts in the construction industry. Certainly, numerous studies have been conducted individually to investigate various smart concepts within the quantity surveying profession in the construction industry. However, there is a lack of research that systematically evaluates the knowledge, perception and impact of current as well as future quantity surveyors concerning various smart concepts in the construction industry. To bridge this knowledge gap among professionals, it is essential to assess the current understanding, perception and impact of smart and technological trends among quantity surveyors. Hence, this study serves as an exploration of the knowledge, perception, and impact of quantity surveyors regarding smart concepts and digital technologies such as BIM, Big Data, Machine Learning, Blockchain, and IoT which have the potential to reshape the quantity surveying profession. Therefore, this research aims to determine the perception and impact of quantity surveyors on new smart concepts and technological trends within the construction industry.

2. Literature review

2.1 ADOPTION OF SMART CONSTRUCTION CONCEPTS AND DIGITALIZATION OF THE CONSTRUCTION INDUSTRY

Industries driven by digital technologies increase growth and development and increase the chance of effectively solving their growth problems (Chiedu, 2010). In the modern world, commercial and industrial sectors such as the banking sector, automobile sector, retailing sector, and manufacturing sector embrace digitalisation for an effective and efficient flow of their day-to-day business activities (Osusanmi et al., 2018). While the other industries fully harness the benefits, the construction industry still slowly adopts digital trends and smart construction concepts (Castagnino et al., 2016). However, Ibem and Laryea (2014) argue that after 2000, the idea of digital technologies gained attention in the construction industry due to the recognition of smart construction concepts like BIM, web-enabled project management applications, and cloud computing. Adopting smart construction concepts through digitalisation in the industry increases time effectiveness, increases productivity, increases the speed of work, increases document quality and accuracy, speeds up response time, and simplifies the working methods while reducing the degree of difficulty, reducing human errors in construction processes relating to quantity surveying profession such as cost control, cost planning, preliminary cost estimation, building system analysis, existing conditions modelling, procurement stages, design authoring, structural analysis, 3D - 4D coordination and preparation and processing of maintenance schedules. (Aghimien et al., 2018).

2.2 BIM AND QUANTITY SURVEYING PROFESSION

BIM is a smart construction concept that provides promising development in the construction industry by producing an accurate virtual computer-generated model and workflow to aid construction-related works (Eastman et al.,

2008). 5D BIM provides a workflow for quantity surveying applications by combining the 3D BIM model of the construction project with the construction schedule and contract price (Fung et al., 2014). Further, Nagalingam et al. (2013) suggest BIM technology is a potential solution for traditional problems in construction estimations. Olatunji and Sher (2014) argue that BIM offers a varying range of solutions for challenges in conventional quantity surveying practice but can provide solutions for all instances. According to a BIM survey in Malaysia conducted by Fung et al. (2014), it was discovered that BIM facilitates rapid cost appraisal, automated quantity extraction, and enhanced visualization, significantly improving efficiency and accuracy in quantity surveying processes during various project stages. These capabilities underscore the transformative potential of BIM in the construction industry.

2.3 BLOCKCHAIN AND QUANTITY SURVEYING PROFESSION

San et al. (2019) recognise potential applications and improvements of blockchain technology to the construction industry in contract management, electronic document management, BIM, property management, supply chain management, and funding management sectors. Smart cities are a topic relating to quantity surveying practice that involves smart governance, smart mobility, smart living, the smart use of natural resources, and smart citizens can be considered critical applications under blockchain 3.0 (Sikorski et al., 2017). Enabling blockchain technology in construction supply chain management can provide a trustworthy system that monitors and analyses its productivity, profitability, and performance at a lower cost. (San et al., 2019).

2.4 BIG DATA AND QUANTITY SURVEYING PROFESSION

Accordingly, Lu et al. (2019) suggested that Big Data is a collection of a large volume of complex data sets that move so fast that it exceeds the processing capacity of traditional database management tools. In the construction industry, quantity surveying professionals deal with large volumes of data. Further, error-prone measurements, time pressure, and inaccurate estimates are the main problems that tend to encounter by quantity surveyors when dealing with large volumes of data. Big Data can provide solutions for these complications as well as increase the efficiency of preparing tenders, biddings, and cost estimates and analysing the bidder's behaviours. Further, it can integrate with BIM to provide more effective service to the client. (Lu et al., 2019).

2.5 MACHINE LEARNING AND QUANTITY SURVEYING PROFESSION

Seyedzadeh et al. (2018) delineate Machine Learning as a way of creating computer algorithms that use a considerable amount of existing data to learn from them and improve their performance. Rafiei and Adeli (2018) introduce a Machine-Learning Model for estimating construction costs considering the available economic variables and indexes using advanced machine-learning concepts. Most Machine Learning solutions tend to provide automation in decision-making in the industries, numerous studies have been published to evaluate the importance and applicability of construction estimates using machine Learning techniques in the construction industry. Additionally, several researchers have proposed systems for the automation of certain complicated stages in the construction process, including construction estimations, bidding decisions, and managing construction project budgeting. Chang et al. (2013) proposed a project profit prediction forecasting system that uses fuzzy clustering and genetic algorithms for project classification with support vector regressor to assist the Machine Learning model for profit margin forecasting.

2.6 IOT AND QUANTITY SURVEYING PROFESSION

IoT has become a technology widely used in many industries to connect the virtual and physical world by providing life-enhancing services (GSMA, 2014). IoT has an impact on construction-related fields such as construction supply chains, smart cities and buildings, and intelligent buildings. Further, Arowoiya et al. (2020) published a paper to assess the adoption of IoT element usage in construction performance and sustainability named "An Appraisal of the Adoption of IoT Elements for Sustainable Construction".

3. Methodology

This research aims to determine the perception and impact of quantity surveyors on new smart concepts and technological trends within the construction industry. According to Creswell (2018), the mixed method which is a combination of both qualitative and quantitative approaches produces more accurate and deep details of the phenomenon. To enhance awareness among quantity surveyors, a mixed-method approach was employed, incorporating expert opinions and industry insights. Yin (2003) asserted that semi-structured interviews are the most effective method for addressing uncertainties arising in response to a study. Additionally, questionnaires were employed as a data collection technique to ascertain the existing perceptions of Quantity Surveyors concerning smart construction concepts. Accordingly, the research employed semi-structured interviews and questionnaires for data collection. Initially, an extensive literature review was conducted to identify knowledge gaps in smart construction concepts related to the quantity surveying profession, drawing upon various sources, such as journal articles, reports, conference papers, books, websites, periodicals, and electronic resources. Subsequently, semi-structured expert interviews (P1, P2, and P3) were conducted to gather insights from experienced professionals regarding methods to disseminate knowledge and enhance awareness of smart construction concepts within the profession. Moreover, these preliminary interviews were instrumental in validating the findings from the literature review and served as a basis for constructing an effective questionnaire survey. Since data saturation was reached, these preliminary

interviews were limited to three experts. Accordingly, all three participants in the interviews were highly experienced quantity surveying professionals with significant exposure to smart construction concepts.

Thereafter, the questionnaire survey was carried out among the quantity surveying professionals actively engaged in the industry and quantity surveying undergraduates (as future professionals) to determine their awareness and perceptions of smart and digital concepts related to the quantity surveying field. Moreover, the purposive sampling method was employed to collect data from experts with expertise in quantity surveying, smart concepts, and digital technology within the construction industry. A detailed questionnaire survey was distributed to 120 construction industry professionals with expertise in quantity surveying, smart concepts, and digital technology focusing mainly on BIM, Big Data, IoT, Blockchain, and Machine Learning within the construction industry, and 50 individuals responded, resulting in a response rate of 41.6%. In the questionnaire survey, respondents were tasked with rating the criticality, efficacy, and efficiency of quantity surveyors' awareness concerning smart construction concepts in the construction industry, the influence of these concepts on quantity surveying practices, and the applications of smart construction concepts affecting the quantity surveying profession. This evaluation was carried out using a five-point "Likert scale," where 1 denoted "strongly disagree," and 5 represented "strongly agree." Consequently, manual content analysis was utilized to analyse the data gathered from the semi-structured interviews. According to Holt (2014), the RII was deemed highly reliable for ranking factors using quantitative data analysis. Hence, to improve the statistical analysis of the Likert scale responses, the RII method was employed to analyse the data collected from the questionnaire survey using SPSS software.

4. Research findings

In this study, a two-stage approach was employed. Firstly, three preliminary interviews with industry professionals were conducted to validate the literature findings and determine the optimal method for data collection and analysis. Subsequently, a comprehensive questionnaire survey was carried out to assess the perception of quantity surveyors regarding smart construction concepts, including their awareness of these concepts in the construction industry, their impact on quantity surveying practice, and their applications affecting the quantity surveying profession. The following sections provide detailed insights into the findings of this research study.

4.1 SMART CONSTRUCTION CONCEPTS AND IMPACT ON THE QUANTITY SURVEYING PROFESSION

According to P1, all the mentioned technologies have a positive impact on the quantity surveying profession, except Machine Learning, which raises concerns about the potential of AI algorithms altering the role of quantity surveyors. On the other hand, P2 presented that all these technologies have a positive impact on the quantity surveying profession since they can lead to new opportunities and roles for quantity surveyors as BIM technology opens up new paths such as BIM management, BIM modelling, and BIM coordination. Further, P2 stated that BIM competency is necessary for future quantity surveyors. Nevertheless, P3 mentioned that all the technologies discussed above positively impact the quantity surveying profession except for IoT. According to P3, IoT has no impact on the quantity surveying profession, but it has an impact on other professions in the construction industry, such as project management. Accordingly, P3 pinpointed a positive impact on BIM as follows; expands the cost estimation possibilities, supports supplier price integration, leads to more accurate budget estimations, and increases the collaboration between stakeholders.

However, P3 argued that having inadequate competencies with BIM among the professionals who work with BIM-based projects could lead to a negative impact on the project. P3 recognized that Big Data and Machine Learning are technologies that should merge with other technologies to provide a considerable outcome to the quantity surveying profession. For instance, Big Data and Machine Learning can be used to manage construction data. Machine Learning combined with BIM could lead to better resource planning and scheduling, and Machine Learning and AI combination can lead to improving inspection quality, and it can reduce costly errors.

4.2 THE AWARENESS OF QUANTITY SURVEYORS' KNOWLEDGE OF SMART CONSTRUCTION CONCEPTS RELATING TO THE CONSTRUCTION INDUSTRY

The BIM knowledge level of the professionals who responded to the questionnaire can be analysed as follows in Table 1. The questionnaire survey indicates that only 4% of the total did not know about BIM, while 68% had moderate or higher BIM proficiency. Among them, 34% have intermediate knowledge, and 30% have moderate knowledge. Only 4% of them have expert knowledge regarding BIM. Twenty-eight per cent of professionals have basic knowledge of BIM. The Big Data knowledge level of the professionals who responded to the questionnaire can be analysed as follows Table 1. According to the data represented above, 30% of the total population does not know Big Data, while 2% of total respondents have expert knowledge. Sixty-eight per cent of the professionals had basic, moderate or intermediate knowledge of Big Data. It includes 26% of the basic knowledge category, 26% of the intermediate knowledge category and 16% of the moderate knowledge category. The Machine Learning knowledge level of the professionals who responded to the questionnaire can be analysed as follows Table 1. Data represented indicates that there was a decrease in knowledge level in higher knowledge classes. The majority of the professionals had no knowledge or basic knowledge of Machine Learning. According to the received data, 30% of the respondents had no idea about Machine Learning, and 2% of the respondents had expert knowledge of Machine Learning. Further, 38%

of the professionals had a basic knowledge of Machine Learning. Additionally, the Moderate and Intermediate knowledge categories had a 20% and 10% response rate.

Table 1: The awareness of quantity surveyors' knowledge of smart construction concepts relating to the construction industry.

No	Smart Construction Concepts	No Knowledge		Basic Knowledge		Moderate Knowledge		Intermediate Knowledge		Expert Knowledge		Total	
		f	%	f	%	f	%	f	%	f	%	f	%
1	BIM Knowledge	2	4%	14	28%	15	30%	17	34%	2	4%	50	100%
2	Big Data Knowledge	15	30%	13	26%	8	16%	13	26%	1	2%	50	100%
3	Machine Learning Knowledge	19	38%	15	30%	10	20%	5	10%	1	2%	50	100%
4	Blockchain Knowledge	18	36%	13	26%	11	22%	6	12%	2	4%	50	100%
5	IoT Knowledge	18	36%	13	26%	11	22%	6	12%	2	4%	50	100%

The blockchain knowledge level of the professionals who responded to the questionnaire can be analysed as follows Table 1. Data representing the Blockchain knowledge indicates a similar trend to Machine Learning knowledge, while the knowledge level decreases in higher knowledge classes. Accordingly, basic, moderate and intermediate knowledge classes received 26%, 22% and 12% response rates. The majority of the professionals do not have any knowledge of Blockchain technology, while the minority among them had a piece of expert knowledge. Commensurately, 36% of professionals did not know Machine Learning, while 4% of them have expert knowledge. The IoT knowledge level of the professionals who responded to the questionnaire can be analysed as follows in Table 1. The IoT knowledge level of professionals has indicated the same trend as the Machine Learning and Blockchain knowledge levels of professionals. The majority of professionals do not know about IoT, which is equivalent to 36% of the total population, and only 2% of the professionals have expert knowledge. However, basic, moderate and intermediate knowledge categories have response rates of 26%, 22% and 12% of the total population.

4.3 THE IMPACT OF SMART CONSTRUCTION CONCEPTS ON QUANTITY SURVEYING PRACTICE

4.3.1 Impact of BIM on Quantity Surveying Practice

Following Table 2 data was collected to identify the impact of BIM on the quantity surveying profession. Accordingly, the majority of professionals argue that BIM has a positive impact on the quantity surveying profession. In contrast, 4% of professionals expressed that BIM has no impact on the quantity surveying profession. According to most professionals, the overall impact of BIM in quantity surveying practice can be expressed as positive. The responses to the questionnaire survey regarding the factors identified through literature review and preliminary interviews relating to BIM application and its impact on quantity surveying practice were subjected to the RII according to the values given in Table 3. Subsequently, factors were ranked according to their importance.

According to the data analysis done subject to Table 3, the BIM application that affects the quantity surveying profession most is "Improve visualization for better understanding." It gained a 0.904 RII value while the second most crucial factor, "Preliminary cost plan can be prepared by extracting quantities from the model" and "Clash detection reduces design errors and cost estimates revisions," scored 0.854 RII value. "Intelligent information management allows data to be stored in a centrally coordinated model" was the fourth most important factor regarding the BIM application and quantity surveying practice with a 0.852 RII value. "Design changes reflected consistently in all drawing views" and "Easily update cost plan more details as the design developed" scored 0.848 and ranked as the fifth most important factor. Respectively, "Cost implication of design changes can be generated easily without manual remeasurement", "Easily generate accurate cost estimates for various design alternatives", "Automatically quantification for BQ preparation", "Cost appraisal can be prepared quickly at feasibility stage" and "Cost checking performs quickly to ensure all items are captured" gained 0.84, 0.824, 0.804, 0.78 RII values. Additionally, several responses consisted of the following applications of BIM by stating they affect the quantity surveying profession such as integration with the contract management process, providing a common platform for various professionals to avoid conflicts and improve communication, integration with whole life cycle costing applications and combination of BIM aspects and Virtual Design and Construction (VDC).

4.3.2 Impact of Big Data and Machine Learning on Quantity Surveying Practice

The following Table 2 quantified the impact of Machine Learning in quantity surveying practice. In consonance with the data collected, about 62% of the professionals stated that Machine Learning has the potential to contribute a positive impact on the quantity surveying profession. In comparison, 6% of the total argue it has the potential to impact negatively, and 32% agreed that it has no impact on the quantity surveying profession. Subsequently, Machine Learning can be considered a smart construction concept that has a potentially positive impact on the quantity surveying profession. The following Table 2 data illustrates the impact of Big Data on the quantity surveying profession. According to collected data, 86% of the professionals agreed that Big Data has the potential to positively

affect quantity-surveying practice, while 7% of the professionals argue there is no impact on the quantity surveying profession.

Since Big Data and Machine Learning technologies are often used as a combination, applications, and effects on the quantity surveying profession are analysed together through the RII according to the values that were given in Table 3. Table 3 represents the potential and current applications of Big Data and Machine Learning that affect the quantity surveying profession. They were ranked according to the RII. Accordingly, the most crucial application was "Using Big Data and Machine Learning to Construction Waste Management," with an RII value of 0.744. Using Big Data and Machine learning for construction site safety prediction and construction project success prediction are ranked as the second most important applications with an RII rating of 0.732. Using Big Data analysis to manage data in EDM systems and Structural Damage Analysis scored 0.728 RII value as the fourth most important factor. "Big Data with Augmented Reality for Problem Simulation and solution generation in Huge Buildings, towns, and Neighbourhoods" and "Using Big Data and Machine Learning to Automate Construction Project Documentation" ranked in sixth place with an RII value of 0.724. Subsequently, using Big Data analysis to manage construction supply chain data, prediction of construction project delay with Big Data and Machine Learning, and managing contractual documentation with Big Data analysis gained RII values of 0.720, 0.716, and 0.608.

4.3.3 Impact of Blockchain on the Quantity Surveying Practice

Following Table 2 data was collected to quantify the impact of Blockchain technology on the quantity surveying profession. Collected data indicates that the Blockchain concept has a potentially positive impact on quantity surveying practice. Eighty percent of professionals agreed with that, while 2% of professionals argue that it has a negative impact and 18% state it has no impact. Potential applications of Blockchain that affect the quantity surveying profession are analysed and ranked with the RII as follows in Table 3.

Table 3 depicts the level of importance regarding potential Blockchain applications according to RII values calculated. Accordingly, the Integration of financial management and cost handling with blockchain was ranked as the most important application with an RII rating of 0.7. Respectively, integration with EDM systems to record data in the Blockchain framework was ranked as the second most important factor with an RII value of 0.688. Further, with an RII score of 0.684, Integration of construction supply chain management with blockchain ranked as the third most important factor. Providing notarial and legal agreements related to construction by integrating with BIM ranked as the fourth most important factor regarding the Blockchain applications relating to quantity surveying practice with an RII value of 0.688. Effective contract management and using Blockchain-based cryptocurrencies as a mode of payment for Construction procurement earned 0.664, and 0.652 RII values, respectively.

4.3.4 Impact of IoT on the Quantity Surveying Practice

The following Table 2 data express the impact of IoT on the quantity surveying profession. According to the data shown in Table 2, most professionals agree that IoT has a positive impact on quantity surveying, while professionals and 24% of them disagree. Among them, 2% argue IoT has a negative impact on the quantity surveying profession, while 22% state it has no impact. IoT applications that affect quantity surveying practice were analysed and ranked according to the RII as follows in Table 3.

In proportion to data expressed in Table 3, "Using IoT to connect head office resources and on-site resources" was the most critical application, along with an RII rating of 0.768. Further, "Using IoT to the real-time observation of construction process" received an RII value of 0.752 as the second important factor. "Tracking and locating Construction Materials with IoT" gained 0.748 value in RII as the third important IoT application relating to quantity surveying practice. Subsequently, "Using wearables to track labourers and their working hours" has gained an RII value of 0.736. Additionally, several professionals mentioned the following applications of IoT that influence the quantity surveying profession such as using IoT for performance and invoice reconciliation and use of asset tracking records for claims mitigation or resolution.

Table 2: Smart Construction Concepts Impact on the Quantity Surveying Profession

Smart Construction Concepts Impact	Frequency	Percentage%
BIM Impact		
Negative impact	0	0%
Positive Impact	46	92%
No Impact	4	8%
Total	50	100%
Big Data Impact		
Negative impact	0	0%
Positive Impact	43	86%
No Impact	7	14%
Total	50	100%
Machine Learning Impact		
Negative impact	3	6%
Positive Impact	31	62%

No Impact	16	32%
Total	50	100%
Blockchain Impact		
Negative impact	1	2%
Positive Impact	40	80%
No Impact	9	18%
Total	50	100%
IoT Impact		
Negative impact	1	2%
Positive Impact	38	76%
No Impact	11	22%
Total	50	100%

Table 3: Ranking of Smart Construction Concept applications that can affect the Quantity Surveying profession.

No	Smart Construction Concept Applications that Can Affect the Quantity Surveying Profession	RII	Rank
BIM Application			
1	Improve visualization for a better understanding of design.	0.904	1
2	A preliminary cost plan can be prepared by extracting quantities from the model.	0.856	2
3	Clash detection reduces design errors and cost estimate revisions.	0.856	2
4	Intelligent information management allows data to be stored in a centrally coordinated model.	0.852	4
5	Design changes reflected consistently in all drawing views	0.848	5
6	Easily update the cost plan with more details as the design developed	0.848	5
7	The cost implication of design changes can be generated easily without manual remeasurement	0.84	7
8	Easily generate accurate cost estimates for various design alternatives	0.824	8
9	Automatically quantification for BOQ preparation	0.824	9
10	Cost appraisal can be prepared quickly at the feasibility stage	0.804	10
11	Cost checking performs quickly to ensure all items are captured	0.78	11
Big Data & Machine Learning Application			
1	Using Big Data and Machine Learning in Construction Waste Management	0.744	1
2	Using Big Data and Machine Learning to Predict Construction Site Safety	0.732	2
3	Using Big Data and Machine learning for construction project success prediction	0.732	2
4	Using Big Data analysis to manage data in EDM systems.	0.728	4
5	Using Big Data and Machine Learning for Structural Damage Analysis	0.728	4
6	Big Data with augmented reality for problem simulation and solution generation in huge buildings, towns, and neighbourhoods	0.724	6
7	Using Big Data and Machine Learning to Automate Construction Project Documentation	0.724	6
8	Manage construction supply chain data with Big Data Analysis.	0.72	8
9	Using Big Data and Machine Learning to Predict Construction Project Delay	0.716	9
10	Using Big Data analysis to manage contractual documentation within construction projects.	0.608	10
Blockchain Application			
1	Integration of financial management and cost handling with blockchain	0.7	1
2	Integration with EDM systems to record data in the Blockchain framework	0.688	2
3	Integration of construction supply chain management with blockchain.	0.684	3
4	Provide notarial and legal agreements related to construction by integrating with BIM	0.668	4
5	Contract Management can be done effectively	0.664	5
6	Using Blockchain base cryptocurrencies as a mode of payment for Construction procurement	0.652	6
IoT Application			
1	Using IoT to connect head office resources and on-site resources.	0.768	1
2	Using IoT for the real-time observation of the construction process	0.752	2
3	Tracking and locating Construction materials	0.748	3
4	Using Wearables to track labourers and their working hours	0.736	4

5. Discussion of findings

Castagnino et al. (2016) emphasized the influence of the IT sector's evolution on reshaping the construction industry efficiently. Various studies, including those by Fung et al. (2014), Lu et al. (2019), Olatunji and Sher (2014), and Sikorski et al. (2017), underscored the necessity for the quantity surveying profession to align with the industry's progress, embracing emerging smart concepts and technological advancements to maintain effectiveness and relevance. Consequently, the evolution of the construction industry and the quantity surveying profession are

interconnected; advancements in one domain invariably impact the other. Seidu et al. (2019) highlighted the potential of smart technologies like BIM, Big Data, blockchain, the IoT, and Machine Learning, enabling quantity surveyors to delve deeper into intricate aspects of construction cost management, and offering innovative and efficient solutions. Similarly, findings from preliminary interviews and questionnaire surveys affirmed that smart construction concepts, particularly BIM, Big Data, blockchain, the IoT, and Machine Learning technologies have positively impacted the quantity surveying profession. However, concerns arose regarding Machine Learning, hinting at the transformative potential of AI algorithms in reshaping the role of quantity surveyors. Despite this, the study revealed these technologies open new avenues and roles for quantity surveyors, notably in BIM management, modelling, and coordination. Furthermore, the study indicated varying levels of awareness among quantity surveyors, with most possessing basic to intermediate knowledge of smart construction concepts. Among these technologies, BIM stood out with a higher level of awareness, signifying its satisfactory perception among industry professionals.

Fung et al. (2014) identified 11 key BIM capabilities that positively affect the role of quantity surveyors. These capabilities include the ability to quickly prepare cost appraisals during the feasibility stage, generate preliminary cost plans by extracting quantities from the model, update cost plans as designs evolve, produce accurate cost estimates for various design alternatives, ensure consistent reflection of design changes across all drawing views, easily calculate the cost implications of design modifications without manual remeasurement, streamline clash detection to minimize design errors and cost estimate revisions, perform efficient cost checking to capture all items, enhance design visualisation for better understanding, automate quantification for BOQ preparation, and centralise information management for coordinated data storage. The study validated all these 11 BIM applications that impact the Quantity Surveying profession, highlighting "Improved visualization for a better understanding of design" as a particularly significant application among them. Furthermore, the research also indicated that, based on RII values, BIM's impact on the quantity surveying profession surpasses that of other smart construction concepts. Additionally, the literature review underlined the significant impact of smart construction concepts like Big Data, Machine Learning, Blockchain, and IoT on the quantity surveying profession. Specifically, the study identified ten applications related to Big Data and Machine Learning, six associated with Blockchain, and four pertaining to IoT that can significantly affect the Quantity Surveying profession. Despite this, the research indicates a positive perception and acceptance of these technologies among quantity surveyors, with the potential for further enhancement in their roles within the evolving construction industry. Although there's a need for quantity surveyors to enhance their knowledge of these technologies, their positive impact on the industry and profession is evident.

6. Conclusion and Recommendation

Modernization has necessitated professionals within the industry to upgrade their knowledge to stay relevant. In light of the ongoing discourse among researchers about smart construction concepts and their applications in construction, this study specifically delved into understanding "How smart construction concepts impact quantity surveying practice" and "How to enhance quantity surveyors' knowledge regarding these concepts." Accordingly, each research objective was meticulously addressed, and recommendations were formulated to enhance the expertise of quantity surveyors as industry professionals. The study's foundational understanding of smart construction concepts such as BIM, Big Data, Machine Learning, Blockchain, and IoT was established through an extensive literature review, and subsequently validated via preliminary interviews to ensure its relevance. The questionnaire survey quantified the awareness levels of quantity surveyors concerning smart construction concepts. The findings indicated that professionals possessing expert knowledge in all the considered smart construction concepts were limited. Notably, a significant majority of quantity surveying professionals exhibited basic to intermediate knowledge in BIM, although those lacking any knowledge in BIM were minimal. However, when it came to emerging areas such as Big Data, Machine Learning, Blockchain, and IoT, a substantial portion (more than 30%) lacked any knowledge. Most professionals possessed basic to intermediate-level knowledge in these emerging areas, highlighting the need for further education and training to enhance their proficiency in these evolving technologies.
To identify the impact of smart construction concepts on quantity surveying practice, a comprehensive approach utilizing literature findings, preliminary interviews, and questionnaire surveys was employed. Initially, relevant smart construction concepts were identified through an extensive literature review, the accuracy of which was subsequently validated through preliminary interviews. Questionnaire surveys were then utilized to quantify the impact of these concepts on the quantity surveying profession, focusing on critical applications of BIM, Big Data, Machine Learning, Blockchain, and the IoT. The analysis revealed that BIM, Big Data, Blockchain, and IoT received approval from over 75% of professionals, indicating a positive influence on quantity surveying practice. However, 32% of respondents noted no significant impact on quantity surveying practice concerning Machine Learning. Overall, the majority of respondents affirmed the positive impact of all smart construction concepts studied. Moreover, based on RII values, BIM demonstrated a more significant impact on the quantity surveying profession compared to other smart construction concepts.

The research findings strongly support the significant impact of smart construction concepts, including BIM, Big Data, Machine Learning, Blockchain, and IoT, on the practice of quantity surveying, aligning with the evolving landscape of the construction industry. Based on these insights, several recommendations can be proposed to address the burgeoning advancements in the construction sector. Firstly, it is imperative for quantity surveying professionals to proactively upgrade their knowledge to keep pace with modern trends and technologies. Individual responsibility

plays a crucial role in this regard, prompting professionals to engage in Continuous Professional Development (CPD) sessions, participate in webinars, and join relevant social media groups. Additionally, leveraging resources such as books, articles, and blogs can further enhance their expertise. Formal education, including university courses or technical programs, provides structured pathways for knowledge enhancement. Secondly, organizations bear the responsibility of ensuring that their representatives are well-versed in these emerging areas. Employing diverse educational programs, such as CPD sessions, webinars, specialized training sessions, and formal education collaborations with universities or other institutions, can facilitate the upskilling of their workforce. By continuously upgrading skills and knowledge, both individuals and organizations can thrive in the rapidly evolving landscape of the construction industry.

Furthermore, this study suggests the extension of similar research initiatives to other professionals within the construction domain, such as architects, project managers, engineers, and facility managers. Exploring the impact of digital twin and Virtual Design and Construction (VDC) technologies in a similar manner could also provide valuable insights for the industry's future developments. Indeed, the findings from this study provide a crucial foundation for the next phase of research. The focus will now shift towards developing effective strategies to enhance the knowledge of quantity surveyors regarding these smart technologies. Additionally, the research will delve into creating a comprehensive framework for the proper integration and application of these technologies within the quantity surveying domain. This next phase aims to refine and implement practical methods, ensuring that quantity surveyors are well-equipped to utilize these smart technologies effectively in their professional practices.

7. References

AECOM. (2014). The Blue Book 2014 - Property and Construction Handbook. AECOM Technology Corporation.

Aghimien, D., Aigbavboa, C., Oke , A., & Koloko, N. (2018). Digitalisation in Construction Industry Construction Professionals perspective. Johannesburg.

Ashworth, A., Hogg, K., & Higgs, C. (2013). Willi's practice and procedure for Quantity Surveyor. West Sussex: Jhon Wiley & Sons Inc.

Autodesk. (2020). What are the benifits of BIM? Retrieved from https://www.autodesk.com: https://www.autodesk.com/solutions/bim/benefits-of-bim

Badu, E., & Amoah, P. (2004). Quantity Surveying Education In Ghana. The Hgana Engineer.

Castagnino, S., Rothballer, C., & Gerbert, P. (2016, 04 04). What's the future of the construction industry? Retrieved from World Economic Forum: https://www.weforum.org/agenda/2016/04/building-in-the-fourth-industrial-revolution/

Chang, P. T., Hung, L. T., Pai , P. F., & Lin, K. P. (2013). Improving project-profit prediction using a two-stage forecasting system. Computers & Industrial Engineering, 800-807.

Chiedu, H. H. (2010). Assessment of the Aplication of Information and Communication Technology in Real Estate Practice(A Case Study of Lagos Metropolis) . Dessertation submitted to the Department of Estate management for Award of M.Sc in Real Estate Management in University of Nigeria Enugu Campus.

CIQS. (2020). Professional Quantity surveyor PQS Designation. Retrieved from http://www.ciqs.org:http://www.ciqs.org/english/designations-defined- professional-quantity-surveyor

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2008). BIM Handbook. New Jersey: John Wiley & Sons Inc.

Fung, W. P., Salleh, H., & Rahim, F. A. (2014). Capability of Building Information Modeling Application in Quantity Surveying Practice. Journal of Surveying, Construction and Property (JSCP), 5(1).

Ghosh, A., Edwards, D. J., & Hosseini, M. R. (2020). Patterns and trends in Internet of Things (IoT) research: future applications in the construction industry. Vol. 28 (No. 2), pp. 457-481. doi:10.1108/ecam-04-2020-0271

GSMA. (2014). Understanding the Internet of Things (IoT). London: GSM Assosiation.

Hussain, K., Salleh, M. N., Talpur, S., & Tulper, N. (2018). Big Data and Machine Learning in Construction: A Review. International Journal of Soft Computing and Metaheuristics, 2-4.

Ibem, E. O., & Laryea, S. (2014). Survey of digital technologies in procurement of construction projects. Automation in Construction, 11-21. doi:doi:10.1016/j.autcon.2014.07.003

Lu, W., Lai, C. C., & Tse, T. (2019). BIM and Big Data for Construction Cost Management. New York: Routledge.

Nagalingam, G., Jayasena, H. S., & Ranadewa, K. (2013). Building Information Modeling and Future Quantity Surveyor's practice in Sri-Lankan Construction Industry. The Second World Construction Symposium 2013: Socio-Economic Sustainability in Construction. Colombo.

Olatunji, O. A., & Sher, W. (2014). Perspectives on Modelling BIM-enabled Estimating Practices. Australasian Journal of Construction Economics and Building.

Oracle Corporation. (2021). What is Big Data. Retrieved from https://www.oracle.com: https://www.oracle.com/big-data/what-is-big-data/

Osusanmi, T. O., Aigbavboa, C., & Oke, A. (2018). Construction 4.0: The Future of the Construction Industry in South Africa. World Academy of Science, Engineering and Technology International Journal of Civil and Environmental Engineering, 12, 150-156.

Perera, S., Nanayakkara, S., & Weerasooriya, T. (2021). Blockchain: The Next Stage of Digital Procurement in construction.

Rafiei, M.H. and Adeli, H., 2018. Novel machine-learning model for estimating construction costs considering economic variables and indexes. Journal of construction engineering and management, 144(12), p.04018106.

RICS. (2020). RICS Futures report. Royal Institution of Chartered Surveyors.

Rodrigo, M. N., Srinath, P., Senaratne, S., & Jin, X. (2018). Blockchain for Construction supply chains: A literature synthesis. ICEC-PAQS Conference 2018. Sydney : Western Sydney University.

Said, I., Safiei, M. W., & Omran, A. (2010). The competency requirement for Quantity Surveyors: Enhancing continuous professional development. ACTA TECHNICA CORVINIENSIS - Bulleting of Engineering.

San, K. M., Choy, C. F., & Fung, W. P. (2019). The Potentials and Impacts of Blockchain Technology in Construction Industry: A Literature Review. IOP Conf. Series: Materials Science and Engineering. IOP Publishing.

Seidu, R. D., Young, B. E., Clack, J., Adamu, Z., & Robinson, H. (2020). Innovative changes in Quantity Surveying Practice through BIM, Big Data, Artificial Intelligence and Machine Learning. 37-47. doi:10.18576/asuj/040105

Seyedzadeh, S., Rahimian, F.P., Oliver, S., Rodriguez, S. and Glesk, I., 2020. Machine learning modelling for predicting non-domestic buildings energy performance: A model to support deep energy retrofit decision-making. Applied Energy, 279, p.115908.

Sikorski, J. J., Haughton, J., & Kraft, M. (2017). Blockchain technology in the chemical industry: Machine-to-machine electricity market., (pp. 234 – 246).

Zhang, Y., Luo, H., & He, Y. (2015). A system for tender price evaluation of construction project based on big data. Creative Construction Conference 2015. 123, pp. 606-614. Wuhan: Procedia Engineering. doi:doi:10.1016/j.proeng.2015.10.114