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Digital Transformation and the Construction Industry Research Landscape: Exploring the Evolving Research Methods

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ABSTRACT

The construction industry has experienced a lot of digital transformation during the present industrial revolution. This transformation has disrupted every aspect of the construction industry. However, little attention has been paid to the impact of this technology-driven disruption on the research landscape. This study aims to identify the present research methods and approaches to check for a commensurate transformation in the research landscape. To achieve this, a bibliometric review was carried out. The data for the study was extracted using keywords from the Scopus database, and the analysis was done using VosViewer. It was observed that researchers are moving more towards the adoption of mixed methods research. Also, researchers are adopting technology-driven research methods (data collection and analysis).

Keywords: Construction research 4.0, Research methodology, Research focus

INTRODUCTION

The construction industry is no longer the same as it used to be in previous industrial revolutions. In recent times, the construction industry has witnessed a lot of transformation due to the present technological revolutions (Adekunle *et al.*, 2021). These emerging technologies in the fourth industrial revolution (e.g blockchain, artificial intelligence, Building information modelling among others) have greatly impacted every facet of the industry (Ejohwomu *et al.*, 2021). These studies point to the impact of the many emerging technologies, benefits, and other dynamics regarding the adoption of several emerging technologies and innovations. Another good

thing observed is that, unlike previous industrial revolutions, the construction industry is more responsive to technology adoption.

These revolutions and transformations have not only impacted practical or industry practitioners but have also seen increased research interests from built environment researchers. As the technology adoption landscape continuously changes, there are commensurate efforts to achieve its widespread diffusion through research. Efforts have been made to capture the trend, albeit for specific technologies. For instance so Olawumi, Chan and Wong (2017) researched the evolution of BIM knowledge via a review of existing work. However, there is a dearth of holistic attention on the evolving research landscape in the digital transformation era and the method adopted. Heretofore, the research methodology and approach adopted by researchers are primarily formulated based on conventional approaches; hence, most standpoints are taken and done based on existing methods from previous industrial revolutions.

The research method deals with how research aims and objectives are achieved, specifically focusing on the data collection and analysis procedure. It is a critical aspect of the "how" of the research. MacDonald, & Headlam (2014) divides this into two aspects: qualitative and quantitative. The study opines that every researcher is either to count things, talk to people, or do both while conducting research. Creswell (2014) describe these two as "*using words (qualitative) rather than numbers (quantitative) or using closed-ended questions (quantitative hypotheses) rather than open-ended questions (qualitative interview questions)*". Although the quantitative approach has been identified to be more prevalent over the centuries, qualitative research only became popular during the second half of the 20th century, thereby reducing the popularity of quantitative research (Sotirios Sarantakos, 2013).

However, it should be noted that there is a clear distinction between research method and research methodology. Research methodology dwells on the theoretical analysis of the methods applied in the study. Furthermore, it encompasses the process of the research, including the principles, theories, and values underpinning the choice and use of research methods. Research methodology is better understood and applied using the research onions (Saunders, Lewis and Thornhill, 2019). It is, therefore, to be noted that Research methods are a subset of research methodology.

A second look at the popularity and adoption dynamics between quantitative and qualitative research over the centuries, therefore, calls for a look into the present methods adopted due to the catalytic disruption introduced by the present digital transformation, especially in the construction industry. Thus, this study identified the various research methods adopted vis-à-vis the research areas in the digital transformation era. This was done to identify if there is a commensurate transformation in the research landscape, such as in the industry.

This study identifies the transformation in research methodologies within the construction industry; thus, it offers valuable insights into how academic and practical research approaches have shifted. Thus, highlighting the need for continuous methodological adaptation to stay abreast of the

technological disruptions that the industry faces. It offers a foundation for understanding the trajectory of research methodologies.

METHOD

To achieve the study objectives, the study adopted a bibliometric approach. The data from the study was extracted from the Scopus database using keywords. These search keywords pull out all studies related to the keywords used in searching through publication titles, abstracts and keywords. To achieve specificity, the keywords adopted for the study and the Boolean connectors are "research" AND "method*" AND "AEC" OR "construction industry" OR "built environment". The returned results are based on the keywords searched for in abstracts, titles and keywords of the publications. The choice of the Scopus database is due to its observed completeness, and thus, it has been adopted in several existing studies (Aghimien *et al.*, 2019; Saka, Olawumi and Chan, 2019; Adekunle, Ejohwomu and Aigbavboa, 2021). Also, the study focused on the post-COVID-19 pandemic era, i.e. from 2020 to mid-2024. This is due to the observation that the COVID pandemic was a major disruptor for technology adoption, especially in the construction industry (Adekunle *et al.*, 2023). The study wants to identify the research methods in this era. The search provided over 11,000 results; however, after the application of exclusion and inclusion criteria to ensure the data was tailored to the research aim, the following exclusion criteria were applied: Engineering as the subject area, only journal articles were selected, and the language of publication was limited to English language, which produces 3088 documents adopted for the study. The choice is because the study considers articles to be more detailed and comprehensive. The collected data was analysed using the Vos viewer visualisation software (van Eck and Waltman, 2019). Other information about the collected data are

Average citation per document – 8.822
Total references – 168880
Authors – 7848
Authors of single-authored docs – 194
Single-authored docs – 207
Co-Authors per Doc – 3.68
Sources of documents – 432

For inclusion in the analysis, the threshold of 5, which is the default threshold, was adopted for the cooccurrence of keywords using the "all keywords" option.

FINDINGS

The findings of the study are presented in Figure 1 and Table 1. Figure 1 represents a visualization of a co-occurrence network of terms from a body of research. The clusters are color-coded and represent different thematic areas. Table 1 presents the clusters showing the research focus areas and the research methodology based on the clusters in Figure 1.

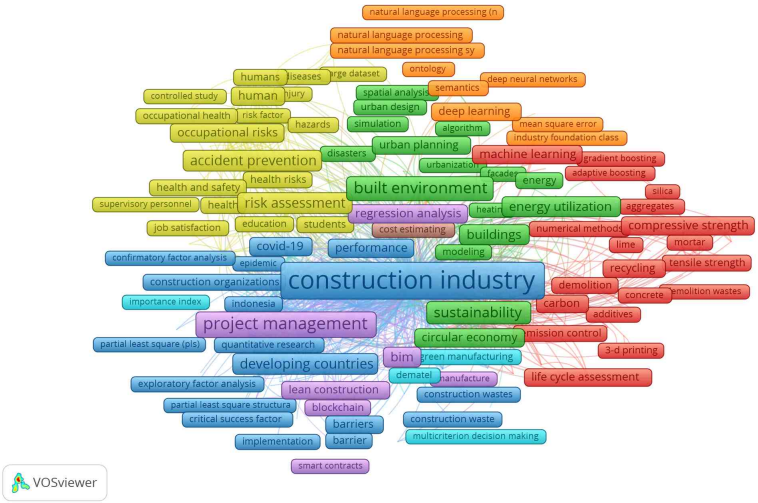

Figure 1: Network visualisation.

Table 1: Clusters of the research focus and research methodology.

Area	Methodology
1	
3D printing	Forecasting
Additive manufacturing	Linear regressing
Building lifecycle	Machine learning
Building materials	Multi-objective
Carbon footprint	optimisation
Digital fabrication	Neural networks
Embodied carbon	Numerical methods
Intelligent building	Optimisation
Lifecycle analysis	algorithm
Modular buildings	Predictive modelling
Recycling	Random forest
Robotics	
Shape optimisation	
Structural design	
Structural optimisation	
Sustainability performance	
Timber construction	
2	
Adaptive management	Agent-based model
Autonomous agents	Behavioural research
Building design and energy	Comparative analysis
Business models	Complex networks
Climate models	Computational fluid
Decarbonisation	dynamics

Continued

Table 1: Continued

Area	Methodology
Decision support system	Numerical model
Disaster mgt	Qualitative assessment
Energy savings	System theory
Energy conservation	
Green building	
Green economy	
IAQ	
IEQ	
Occupant model	
Performance assessment	
Sensor	
Smart city	
Solar buildings	
Spatial analysis	
Sustainable cities	
Travel behaviour	
Thermal comfort	
Urban development and design	
Urban design/transport	
User experience	
Zero carbon	
3	
Cloud computing	Computation theory
Construction 4.0	CFA
Construction business	Correlation methods
Construction education	Descriptive stats
Construction enterprise	EFA
Construction innovation	Least square
Construction labours	approximation
Construction performance	Mixed method
Construction practice	Multivariate analysis
Construction stakeholders	PLS
Construction technology	PCA
Construction waste	Quantitative research
Construction workforce	Questionnaire surveys
CSR	Reliability analysis
Digital construction	Statistical mechanics
Economic analysis	
Emerging technologies	
Innovative approaches	
IoT	
Laws and legislation	
Natural resource management	
Project performance	
Project success	
Resource allocation	
Quantity Surveying	

Continued

Table 1: Continued

Area	Methodology
Value management	
Work life balance	
Decision making process	
4	
Accident prevention	ANN
AR	Bayesian network
Communication	Controlled study
Construction accidents	Grounded theory
construction equipment	Fuzzy logic
Construction operations	Discrete event
Construction Safety	simulation
Construction site safety	Interview
Construction work/worker	Meta analysis
Curricula	mixed method
E-learning	research
Engineering education	Online questionnaire
Exoskeleton	Qualitative approach
Hazard identification	/research
Human engineering	Questionnaire surveys
Human experiment	SEM
Human resource management	Systems thinking
Education computing	
Environmental regulation	
Education and learning	
Immersive VR	
Job satisfaction	
Leadership	
Machinery	
Mental health	
Mixed reality	
Musculoskeletal disorder/system	
Occupational safety and risks	
Organisational culture	
Organisational learning	
Performance evaluation	
Personnel training	
PPE	
Information analysis	
Risk factors/perceptions	
Safety engineering	
Safety management	
Social sustainability	
Technology adoption	
Transformational leadership	
Wearable technology	
Unsafe behaviours	
Wages	

Continued

Table 1: Continued

Area	Methodology
5	
BIM	Case based reasoning
Blockchain technology	Case study
Construction contract	Comparative studies
Construction engineering	Design science
Construction management	research
Productivity	ISM
Construction supply chain	Multiple case study
Industrialised construction	Theoretical modelling
Information dissemination	
Knowledge management	
Knowledge transfer	
Lean construction	
Logistics	
Maturity model	
Mega projects	
Modular construction	
Modern methods of construction	
Offsite construction	
Policy making	
Prefabrication	
Project management	
Project delivery	
PPP	
Quality mgt	
Small and medium sized enterprises	
Smart contract	
Stakeholder mgt	
Value engineering	
6	
Adoption barriers	AHP
Cost analysis	Delphi method
Cost overrun	DEMATEL
Green construction	Fuzzy AHP
Lifecycle costing	Game theory
Project delays	Multi Criteria decision
Project risk mgt	making
Scheduling	Multicriteria analysis
Sustainability assessment	Relative importance
Uncertainty analysis	index
7	
AI	Cluster analysis
Automation	Convolutional neural
Big data	network
Building codes	Deep neural networks
Compliance control	

Continued

Table 1: Continued

Area	Methodology
Construction engineering	k Means clustering
Cost engineering	Learning algorithms
CPS	Natural language
Data acquisition	processing
Data handling	Object detection
Data mining	
Deep learning	
Digital twins	
Embedded systems	
Facilities management	
Industrial foundation classes	
IoT	
Interoperability	
Real-time systems	
Regulatory compliance	
Unmanned aerial vehicle	
Transfer learning	
8	
Construction markets	Monte Carlo methods
Cost-benefit analysis	Questionnaire survey
Cost estimating	Semi-structured
Highway engineering	interview
Intelligent systems	Stochastic systems
International construction	Text mining
International trade	
Strategic management	
Social implication	

A quick look at the clusters shows that they are majorly a nexus of emerging technologies and other aspects of innovation and various construction industry practices. Below is each cluster with the theme name ascribed based on the constituent keywords and the research methodology approaches adopted.

- Cluster one (emerging technologies and sustainable construction)

This cluster primarily focuses on predictive analytics and optimization techniques. It utilizes linear regression, machine learning (including neural networks and random forests), numerical forecasting and predictive modelling methods. Multi-objective optimization and optimization algorithms are used to optimize various parameters within models.

- Cluster two (nexus of Smart technologies, Sustainable urban development and management models)

This cluster involves a mix of methodologies focused on understanding complex systems and behaviours. Agent-based modelling, comparative analysis, and computational fluid dynamics are used to simulate and analyze

systems with multiple interacting agents/components. Qualitative assessment and system theory are employed to understand the behaviour of these systems on a conceptual level.

- Cluster three (digital transformation and construction industry product and processes)

This cluster revolves around quantitative research methods and statistical analysis techniques. It includes methods such as computation theory, multivariate analysis (including PCA and PLS), and correlation methods for analyzing relationships and patterns in data. Descriptive statistics, reliability analysis, and questionnaire surveys are used to gather and analyze quantitative data.

- Cluster 4 (Technology, education and well-being)

This cluster encompasses a range of methodologies, including both quantitative and qualitative approaches. It includes techniques such as artificial neural networks (ANN), Bayesian networks, and fuzzy logic for modelling complex systems and decision-making processes. Grounded theory, interviews, and qualitative approaches are employed for in-depth understanding, collection and interpretation of data.

- Cluster 5 (Construction efficiency and management)

This cluster is centred around case-based research methodologies. It includes methods such as case studies, comparative studies, and multiple case studies for analyzing specific instances within a broader context. Design science research and theoretical modelling are used to develop and test theories.

- Cluster 6 (Enhancing sustainability)

This cluster focuses on decision-making methodologies and techniques for evaluating alternatives. Analytic Hierarchy Process (AHP), Delphi method, and multicriteria analysis are used for decision-making, forecasting and prioritization. Fuzzy AHP and fuzzy logic are employed to handle uncertain data.

- Cluster 7 (Efficient data management and exchange)

This cluster involves methodologies related to data analysis and pattern recognition. It includes techniques such as cluster analysis, convolutional neural networks (CNN), and deep neural networks for identifying patterns and clusters within data. Natural language processing (NLP) is used for analysing textual data and object detection for identifying objects within images.

- Cluster 8 (international construction business)

This cluster primarily utilizes probabilistic and stochastic methods for modelling and analysis. Monte Carlo methods are employed for simulating complex systems with uncertainty, while stochastic systems are used to model

systems with random behaviour. Text mining and questionnaire surveys are utilized to gather and analyze textual and survey data.

A critical look at these clusters shows that diverse methodologies have been employed. Some are solely quantitative, while some are qualitative, and some are mixed. However, it will be interesting to see researchers applying other types of methodology that are currently not being adopted in each area. Be that as it may, the researcher is still under the obligation to adopt the right methodology, which is appropriate for the study, based on the study context (Kumar, 2011). It is also worth noting that the research landscape is changing and undergoing a disruptive transformation, as is the case with industry. Most applied data collection and analysis methods are adopting emerging technologies, e.g. AI, ML, etc.

IMPLICATIONS

The digital revolution has substantially changed research methods, particularly in the construction industry. Traditional research, which often focused on either qualitative or quantitative methods, is increasingly being replaced or complemented by mixed methods approaches. This change is primarily driven by the need for more robust and data-driven insights, which digital tools and technologies can better facilitate. As observed in the findings, researchers are increasingly adopting technology-driven methodologies, including artificial intelligence (AI), machine learning (ML), and predictive modelling, which offer the ability to process large datasets and generate previously unattainable insights using conventional methods.

The bibliometric review conducted in this study reflects a broader trend across industries, where digital tools enable more sophisticated data collection and analysis methods. For example, the use of visualization software like VOSviewer helps researchers to analyze vast amounts of data, identify trends, and establish correlations between different variables. This represents a significant departure from traditional approaches, which often relied on manual analysis and simpler statistical tools.

The digital revolution has also led to a democratization of data. With greater access to databases and real-time data analysis tools, researchers are no longer confined to isolated case studies or small data samples. Instead, they can analyze global trends, incorporate large datasets, and apply sophisticated modeling techniques to predict outcomes or optimize processes. This shift has enhanced the precision and relevance of research findings, making them more applicable to real-world scenarios.

CONCLUSION

The study focused on identifying the research methodologies being adopted by researchers in the present technological revolution and how digital transformation in the construction industry has catalyzed a shift in research methodologies. It was observed that researchers are moving more towards adopting mixed methods research. Also, researchers are adopting technology-driven research methods (data collection and analysis). The move

towards mixed methods, with an increasing emphasis on technology-driven approaches like machine learning, neural networks, and predictive analytics, signals that the research landscape is not only evolving but also adapting to the complexities introduced by modern technologies. This shift implies that future research will likely focus on more comprehensive data integration and real-time analysis, fostering innovation and improved decision-making processes in construction practices. However, it is important to research the adequacy of existing philosophies, theories, and approaches to emerging research trends. This is important as the disruption caused by technology significantly impacts existing approaches, even in the construction industry and other sectors. Furthermore, researchers should explore the impact of the emerging data analysis methods on the research outcomes and impact. A comparative analysis can be done on the traditional and emerging research methods to identify the depth of data interpretation they offer.

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