

**DIGITAL PARADIGM IN CONSTRUCTION: ASSESSING THE
ADOPTION DYNAMICS OF BUILDING INFORMATION MODELING IN
GHANA'S CONSTRUCTION INDUSTRY**

DISSERTATION

**Submitted in Partial Fulfilment of the Requirements for a Doctoral Degree in
Technology and Vocational Education**



**By
DANIEL EBO HAGAN
NIM: 2213529**

**DOCTOR OF TECHNOLOGY AND VOCATIONAL EDUCATION
FACULTY OF TECHNOLOGY AND VOCATIONAL EDUCATION
SCHOOL OF POSTGRADUATE STUDIES
UNIVERSITAS PENDIDIKAN INDONESIA**

2025

DANIEL EBO HAGAN

**DIGITAL PARADIGM IN CONSTRUCTION: ASSESSING THE
ADOPTION DYNAMICS OF BUILDING INFORMATION MODELING IN
GHANA'S CONSTRUCTION INDUSTRY**

Approved and authorized by the dissertation committee:

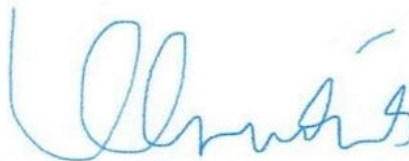
Promotor



Prof. Tutin Aryanti, S.T., M.T., Ph.D.

NIP: 19750815 200312 2 001

Kopromotor



Ilhamdaniah Saleh, M.T., M.Sc., Ph.D.

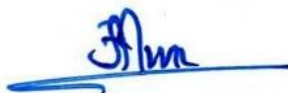
NIP: 19771116 201012 2 001

Acknowledged by:

Head of Doctoral Program in Technology and Vocational Education

School of Postgraduate Studies

Universitas Pendidikan Indonesia



Prof. Dr. Isma Widiaty, M.pd.

NIP. 19710607 200112 2 001

**DIGITAL PARADIGM IN CONSTRUCTION: ASSESSING THE
ADOPTION DYNAMICS OF BUILDING INFORMATION MODELING IN
GHANA'S CONSTRUCTION INDUSTRY**

By

Daniel Ebo Hagan

Universitas Pendidikan Indonesia

Submitted in Partial Fulfilment of the Requirements for a Doctoral Degree in
Technology and Vocational Education

© Daniel Ebo Hagan

Universitas Pendidikan Indonesia

2025

The copyright is protected by law

This dissertation may not be reproduced in whole or in part by reprinting,
photocopying, or other means without the permission of the author.

DANIEL EBO HAGAN, 2025

***DIGITAL PARADIGM IN CONSTRUCTION: ASSESSING THE ADOPTION DYNAMICS OF BUILDING
INFORMATION MODELING IN GHANA'S CONSTRUCTION INDUSTRY***

Universitas Pendidikan Indonesia | repository.upi.edu | perpustakaan.upi.edu

DECLARATION

I hereby declare that this dissertation entitled “**Digital Paradigm in Construction: Assessing the Adoption Dynamics of Building Information Modeling in Ghana’s Construction Industry**” and all its contents are truly my own work. I do not plagiarize or quote in ways that violate scientific ethics that apply to the scientific community. I am ready to bear the risk/sanction if, in the future, there is a violation of scientific ethics or a claim against the authenticity of my work.

Bandung, August 2025

Daniel Ebo Hagan 2213529

ACKNOWLEDGEMENT

With a grateful heart, I first thank the Almighty God, whose grace and strength sustained me throughout this journey. I am humbled by the guidance I have received, and remain deeply grateful to all persons, who, in diverse ways, made this doctoral degree possible.

To begin, I extend sincere thanks to Prof. Dr. H. Didi Sukyadi, MA., Rector of Universitas Pendidikan Indonesia, and his esteemed management team for awarding the generous scholarship that enabled my studies at this respected institution. I am equally grateful to the director, Dr. rer. nat. Nandi, S.Pd., M.T., M.Sc., and the dedicated personnel at the Directorate of International Affairs.

I also express my profound appreciation to Prof. Dr. Juntika Nurihsan, M.Pd., Director of the School of Postgraduate Studies, and to Professor Dr. Ade Gafar Abdullah, S.Pd., M.Si., Vice Director for Academic and Student Affairs, I owe deep gratitude for the unwavering guidance.

I am grateful to Prof. Dr. Eng. Agus Setiawan, M.Si., Dean of the Faculty of Technology and Vocational Education. My gratitude extends to Professor Dr. Isma Widiaty, M.Pd., head of the postgraduate study program, and to her diligent administrator, Pak Depi, for their steadfast encouragement.

I am indebted to my dissertation promoter, Professor Tutin Aryanti, S.T., M.T., Ph.D., and co-promoter Dr. Ilhamdaniah, S.T., M.T., MSc., whose insightful feedbacks were crucial in enriching my research experience. I also thank all the lecturers of the Faculty of Technology and Vocational Education for generously sharing knowledge and insights.

I appreciate the management and staff of Cape Coast Technical University for their continued support. Most importantly, I thank my family for their unwavering love: my beloved wife, Georgina Mensah and the kids; my dear mother, Sarah Dickson; my respected uncles, Rev. K. A. Dickson and Mr. Kobina K. Dickson; and my cherished siblings, Paulina, Ophelia, and Ishmael. Your faith in me sustained every step.

I am also grateful to the international students' community at UPI, especially my Ghanaian family, for their friendship, solidarity, and shared experiences. Finally, to everyone who contributed directly or indirectly to this journey, thank you. Your support and encouragement made this achievement possible.

ABSTRACT

The global construction industry has been criticised for its slow adoption of transformative technologies, with persistent challenges of fragmentation, poor communication, and weak coordination. Building Information Modeling (BIM) has emerged as a promising solution to address these inefficiencies by enhancing collaboration and project delivery. In Ghana, however, BIM adoption remains limited, largely due to systemic, organizational, and contextual barriers. Against the backdrop of global digital transformation, understanding the dynamics of BIM adoption in Ghana is critically important. This study investigated BIM awareness, adoption readiness, influential factors, perceived impacts on project performance, and strategies for effective adoption. An exploratory sequential mixed-methods design was employed, beginning with semi-structured interviews of 21 construction industry stakeholders, followed by a nationwide survey of 380 construction professionals. Qualitative data were analysed thematically, while quantitative data were examined using descriptive statistics, factor analysis, and Structural Equation Modelling (SEM). The findings reveal that although BIM awareness is widespread, practical knowledge and skills remain insufficient. Organizational and technological readiness is also low, characterized by inadequate digital infrastructure, limited strategic planning, and weak leadership support. Key drivers of adoption include improved visualization, collaboration, and cost efficiency, while major barriers include a shortage of skilled professionals, poor IT systems, and lack of regulatory frameworks. Importantly, BIM adoption was perceived to significantly improve project performance by enhancing coordination, project quality, and change order management. The study contributes a context-specific BIM Adoption Framework for Ghana, providing a practical roadmap for implementation. Unlike previous fragmented studies, this research offers the first integrated, industry-wide assessment of BIM adoption in Ghana, filling a critical gap. Theoretically, it advances knowledge on BIM adoption in developing contexts; practically, it provides actionable strategies for policymakers and construction industry stakeholders to drive digital transformation in the construction sector.

Keywords: Building Information Modeling (BIM); Construction Industry; Technology Adoption; Digital Transformation; Project Performance

DANIEL EBO HAGAN, 2025

DIGITAL PARADIGM IN CONSTRUCTION: ASSESSING THE ADOPTION DYNAMICS OF BUILDING INFORMATION MODELING IN GHANA'S CONSTRUCTION INDUSTRY

Universitas Pendidikan Indonesia | repository.upi.edu | perpustakaan.upi.edu

ABSTRAK

Industri konstruksi global telah dikritik karena lambatnya adopsi teknologi yang transformatif, dengan tantangan yang terus-menerus berupa fragmentasi, komunikasi yang buruk, dan koordinasi yang lemah. Building Information Modeling (BIM) muncul sebagai solusi yang menjanjikan untuk mengatasi ketidakefisienan ini dengan meningkatkan kolaborasi dan pelaksanaan proyek. Namun, di Ghana, adopsi BIM masih terbatas, terutama karena hambatan sistemik, organisasional, dan kontekstual. Dalam konteks transformasi digital global, memahami dinamika adopsi BIM di Ghana menjadi sangat krusial. Studi ini menyelidiki tingkat kesadaran terhadap BIM, kesiapan adopsi, faktor-faktor yang berpengaruh, dampak yang dipersepsikan terhadap kinerja proyek, serta strategi untuk adopsi yang efektif. Desain metode campuran sekuensial eksploratori digunakan, dimulai dengan wawancara semi-terstruktur terhadap 21 pemangku kepentingan industri, kemudian dilanjutkan dengan survei berskala nasional terhadap 380 profesional konstruksi. Data kualitatif dianalisis secara tematik, sedangkan data kuantitatif diuji menggunakan statistik deskriptif, analisis faktor, dan Structural Equation Modelling (SEM). Temuan menunjukkan bahwa meskipun kesadaran terhadap BIM sudah luas, pengetahuan dan keterampilan praktis masih belum memadai. Kesiapan organisasional dan teknologi juga rendah, yang ditandai oleh infrastruktur digital yang kurang memadai, perencanaan strategis yang terbatas, serta dukungan kepemimpinan yang lemah. Pendorong utama adopsi mencakup peningkatan visualisasi, kolaborasi, dan efisiensi biaya, sementara hambatan utama meliputi kelangkaan tenaga profesional terampil, sistem TI yang buruk, dan ketiadaan kerangka regulasi. Pentingnya, adopsi BIM dipersepsikan secara signifikan meningkatkan kinerja proyek melalui peningkatan koordinasi, kualitas proyek, dan pengelolaan perubahan pekerjaan (change order). Studi ini menyumbangkan Kerangka Adopsi BIM yang spesifik konteks untuk Ghana, menyediakan peta jalan praktis bagi implementasi. Berbeda dari studi-studi sebelumnya yang terfragmentasi, riset ini menawarkan penilaian terintegrasi pertama secara lintas industri mengenai adopsi BIM di Ghana, sehingga mengisi kesenjangan kritis. Secara teoretis, penelitian ini memperkaya pengetahuan tentang adopsi BIM dalam konteks negara berkembang; secara praktis, penelitian ini menyediakan strategi yang dapat ditindaklanjuti bagi para pembuat kebijakan dan pemangku kepentingan industri untuk mendorong transformasi digital di sektor konstruksi.

Kata Kunci: Building Information Modeling (BIM); Industri Konstruksi; Adopsi Teknologi; Transformasi Digital; Kinerja Proyek.

DANIEL EBO HAGAN, 2025

DIGITAL PARADIGM IN CONSTRUCTION: ASSESSING THE ADOPTION DYNAMICS OF BUILDING INFORMATION MODELING IN GHANA'S CONSTRUCTION INDUSTRY

Universitas Pendidikan Indonesia | repository.upi.edu | perpustakaan.upi.edu

TABLE OF CONTENTS

DECLARATION	iv
ACKNOWLEDGEMENT	v
ABSTRACT	vi
ABSTRAK	vii
TABLE OF CONTENTS	viii
LIST OF TABLES	xvi
LIST OF FIGURES	xviii
LIST OF APPENDICES	xx
CHAPTER 1	1
INTRODUCTION	1
1.1 Research Background.....	1
1.2 Problem Formulation	5
1.3 Research Objectives	6
1.4 Significance of Research.....	7
1.4.1 Theoretical Significance.....	7
1.4.2 Policy Significance.....	7
1.4.3 Practical Significance.....	8
1.4.4 Social Issues and Actions.....	9
1.5 Organizational Structure of Research	10
CHAPTER 2	12
LITERATURE REVIEW.....	12
2.1 Introduction	12
2.2 Study Area - Ghana.....	12
2.2.1 Ghana's Construction Industry	14

2.2.2 Procurement of Construction Works.....	16
2.2.3 Major Construction Professionals	18
2.2.4 Previous BIM Studies in Ghana	20
2.3 Technology Adoption in the Construction Industry.....	21
2.4 Concepts of BIM	23
2.4.1 Level of Development.....	24
2.4.2 BIM Maturity	27
2.4.2.1 Level 0:.....	27
2.4.2.2 Level 1: Object-based modeling:	27
2.4.2.3 Level 2: Model-based collaboration:	28
2.4.2.4 Level 3: Network-based integration:.....	28
2.4.3 BIM Adoption in the Construction Industry	29
2.4.4 Global Trends and Advancement in BIM Technology in the Construction Industry	30
2.4.5 Trends and Advancement of BIM Technology in Ghana's Construction Industry	33
2.5 BIM Awareness and Knowledge	34
2.6 Organizational and Technological Readiness for BIM Adoption.....	36
2.7 Drivers of BIM Adoption.....	38
2.8 Barriers to BIM Adoption	41
2.9 Impact of BIM on Construction Project Performance	43
2.10 Strategies for Effective BIM Adoption	46
2.11 BIM Implementation Initiatives of Three (3) Leading Countries	49
2.11.1 The United Kingdom	50
2.11.2 Singapore	52
2.11.3 The United States of America	54

2.12 Theoretical Framework	55
2.12.1 Technology Acceptance Model.....	55
2.12.2 Diffusion of Innovation Theory	56
2.12.3 Resource-Based View Theory.....	58
2.12.4 Institutional Theory	59
2.12.5 Philosophical Foundations of Digital Technology and Construction Vocations	60
2.12.6 Digital Transformation in the Construction Industry.....	60
2.13 Previous Studies.....	61
2.13.1 BIM Awareness and Knowledge among Construction Professionals	61
2.13.2 Organizational and Technological Readiness for BIM Adoption.....	63
2.13.3 Key Drivers and Barriers Influencing BIM Adoption	65
2.13.4 Impact of BIM Adoption on Construction Project Performance	68
2.13.5 Frameworks for Effective BIM Adoption and Utilization.....	70
2.13.6 Gaps in the Literature.....	72
2.14 Research Framework and Hypotheses	74
2.14.1 Research Framework.....	74
2.14.2 Hypotheses	75
CHAPTER 3	78
RESEARCH METHOD.....	78
3.1 Introduction	78
3.2 Research Philosophy	78
3.3 Research Design.....	79
3.4 Participants.....	81
3.5 Qualitative Research Phase	82
3.5.1 Participants.....	82

3.5.2 Research Procedure	83
3.5.2.1 Research Instruments	83
3.5.2.2 Interview Guide Validation.....	84
3.5.2.3 Qualitative Data Collection.....	85
3.5.3 Qualitative Data Analysis	85
3.6 Quantitative Research Phase	86
3.6.1 Population and Sample.....	86
3.6.1.1 Sample Size Determination.....	87
3.6.1.2 Sampling Technique.....	88
3.6.2 Research Procedure	89
3.6.2.1 Research Instrument.....	89
3.6.2.2 Validity.....	91
3.6.2.3 Reliability.....	92
3.7 Measurement and Operationalisation of Variables	93
3.7.1.1 Quantitative Data Collection.....	99
3.7.2 Quantitative Data Analysis	100
3.8 Triangulation of Qualitative and Quantitative Data.....	102
3.9 Ethical Consideration	103
CHAPTER 4	104
ANALYSIS AND RESULTS	104
4.1 Introduction	104
4.2 Qualitative Data Analysis	104
4.2.1 Respondents' profile	105
4.2.2 BIM Awareness and Knowledge among industry stakeholders	106
4.2.3 Readiness of Ghana's Construction Industry Towards BIM Adoption	110

4.2.4 Drivers of BIM Adoption.....	114
4.2.5 Challenges of BIM Adoption.....	119
4.2.6 Impact of BIM Adoption on Project Outcomes	123
4.2.7 Strategies for Effectively Implementing BIM.....	127
4.3 Quantitative Data Analysis	131
4.3.1 Demographic Information of the Respondents	132
4.3.2 BIM Adoption	134
4.3.2.1 Assessment of the unidimensionality and reliability of the BIM Adoption (BA) construct.....	135
4.3.2.2 SEM for the BIM Adoption Construct.....	136
4.3.3 BIM Awareness and Knowledge	138
4.3.3.1 BIM Awareness.....	138
4.3.3.2 BIM Knowledge.....	147
4.3.3.3 Differences in BIM Awareness and Knowledge Among Construction Professionals.....	155
4.3.4 Organizational and Technological readiness of Ghana's construction industry towards BIM adoption	156
4.3.4.1 Assessment of the unidimensionality and reliability of the Organisational and Technological Readiness construct.....	161
4.3.4.2 SEM for the Organisational and Technological Readiness Construct	162
4.3.4.3 Testing The Influence of Organisational and Technological Readiness on BIM Adoption (BA).....	165
4.3.5 Key Drivers and Barriers Influencing BIM Adoption	168
4.3.5.1 Assessment of the unidimensionality and reliability of the Key Drivers Influencing BIM Adoption construct.....	171
4.3.5.2 SEM for Key Drivers Influencing BIM Adoption	172

4.3.5.3 Testing The Influence of Key Drivers (KD) of BIM Adoption Construct on BIM Adoption (BA)	175
4.3.6 Key Barriers Influencing BIM Adoption	176
4.3.6.1 Assessment of the unidimensionality and reliability of the key barriers influencing the adoption of BIM.....	179
4.3.6.2 SEM for Key Barriers Influencing BIM Adoption Construct.....	180
4.3.6.3 Testing The Influence of the Identified Barriers to BIM Adoption in Ghana's Construction Industry on the extent of BIM Adoption	183
4.3.7 Impact of BIM on Construction Project Performance	185
4.3.7.1 Assessment of the unidimensionality and reliability of the Impact of BIM on Construction Project Performance construct	189
4.3.7.2 SEM for the Impact of BIM on Construction Project Performance Construct	190
4.3.7.3 Testing The Influence of the Adoption of BIM On the Performance of Construction Projects in Ghana	192
4.3.8 Strategies for Effective BIM Adoption	195
4.3.8.1 Assessment of the unidimensionality and reliability of the Strategies for the Effective Adoption of BIM construct	199
4.3.8.2 SEM for the Strategies for Effective Adoption of BIM Construct	201
CHAPTER 5	204
DISCUSSION	204
5.1 Introduction	204
5.2 State of BIM Adoption.....	204
5.3 BIM Awareness and Knowledge among Construction Professionals in Ghana	206
5.3.1 Industry BIM Awareness	207
5.3.2 BIM Knowledge within the Industry	209

5.4 Readiness of Ghana's Construction Industry for BIM Adoption	212
5.5 Drivers and Barriers to BIM Adoption	218
5.5.1 Key Drivers of Adoption.....	218
5.5.2 Key Barriers to Adoption.....	220
5.6 The Impact of BIM Adoption on Construction Project Performance in Ghana	223
5.7 Strategies for Effective BIM Adoption in Ghana's Construction Industry	226
5.8 Framework for BIM Adoption in the Ghanaian Construction Industry....	229
5.8.1 Components of the Framework.....	231
5.8.1.1 Establishment of a National BIM Council	231
5.8.1.2 Development of a National BIM Strategy	232
5.8.1.3 Develop Industry Readiness for BIM Adoption	232
5.8.1.4 Adoption of Best Practices.....	237
5.8.1.5 Pilot BIM-Based Projects.....	238
5.8.1.6 Limited Industry-wide BIM Mandate on New Public-Funded Projects.....	238
5.8.1.7 Full BIM Level 2 Mandate.....	239
5.9 Validation of the Proposed Framework	240
5.9.1 Results of Respondent Validation.....	241
5.9.2 Respondents' Observations	243
5.9.3 Suggestions for Improving the Framework.....	244
5.9.4 Critical Issues that the Framework did not Sufficiently Address	245
5.9.5 Potential Benefits of the Framework	246
CHAPTER 6	248
CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS	248
6.1 Conclusions.....	248

6.1.1 BIM Adoption	248
6.1.2 State of BIM awareness and knowledge	248
6.1.3 Organisational and Technological Readiness	249
6.1.4 Key Drivers and Barriers	250
6.1.5 Impact of BIM on Project Performance	251
6.1.6 Strategies for Effective BIM Adoption	252
6.2 Implications.....	253
6.2.1 State of BIM awareness and knowledge	253
6.2.2 Organisational and Technological Readiness	254
6.2.3 Key Drivers and Barriers	255
6.2.4 Impact of BIM on Project Performance	256
6.2.5 Strategies for Effective BIM Adoption	257
6.3 Recommendations	258
6.3.1 Policy	258
6.3.2 Practice.....	259
6.3.3 Education and Training.....	260
6.3.4 Future Research.....	261
6.4 Limitations of the Study.....	262
REFERENCES.....	263
APPENDICES	291

LIST OF TABLES

Table 2. 1 Key Drivers of BIM Adoption	40
Table 2. 2 Key Barriers to BIM Adoption	43
Table 2. 3 Summary of Theoretical Linkages to Hypotheses	76
Table 3. 1 Population of construction professionals in Ghana.....	86
Table 3. 2 Operationalisation of variables	93
Table 4. 1 Profile of interview participants.....	105
Table 4. 2 Demographic Information of the Respondents	132
Table 4. 3 Robust Fit Index for the BIM Adoption Indicators	136
Table 4. 4 Robust Fit Index for BIM Awareness	143
Table 4. 5 Factor Loading and P-Value of The Effect of the Influence of BIM Awareness on BIM Adoption (BA)	146
Table 4. 6 Robust Fit Index for BIM Knowledge	151
Table 4. 7 Factor loading and P-value of the effect of BIM Knowledge on BIM Adoption (BA)	154
Table 4. 14 One-Way ANOVA Results for Differences in BIM Awareness and Knowledge Among Construction Professionals	155
Table 4. 15 ANOVA Results	156
Table 4. 8 Robust Fit Index for the Organisational and Technological Readiness	163
Table 4. 9 Factor loading and P-value of the effect of Organisational and Technological Readiness on the BIM Adoption (BA).....	167
Table 4. 10 Robust Fit Index for Key Drivers Influencing BIM Adoption	172
Table 4. 11 Factor loading and P-value of the effect of Key Drivers (KD) of BIM Adoption Construct on BIM Adoption (BA)	176
Table 4. 12 Robust Fit Index for Key Barriers Influencing BIM Adoption	181
Table 4. 13 Factor Loading And P-Value of The Effect of The Identified Barriers to BIM Adoption in Ghana's Construction Industry on The Extent of BIM Adoption	184
Table 4. 14 Robust Fit Index for the Impact of BIM on Construction Project Performance	191

Table 4. 15 Factor loading and P-value of the effect of The Adoption of BIM on the Performance of Construction Projects in Ghana	194
Table 4. 16 Robust Fit Index for the Strategies for Effective Adoption of BIM	202
Table 5. 1 Feedback from Validation Findings.....	243

LIST OF FIGURES

Figure 1. 1 Research Organizational Structure	11
Figure 2. 1 Locational map of Ghana Source: Charles Sturt University Spatial Analysis Unit (2015) cited in Cobbinah and Erdiaw-Kwasie (2018)	14
Figure 2. 2 BIM Level of Development (LOD) (TrueCADD, 2023)	25
Figure 2. 3 BIM Maturity Level (Shafiq, 2021) (modified from the Bew-Richard BIM maturity model)	28
Figure 2. 4 BIM implementation process (Pan et al., 2023)	30
Figure 2. 5 The Global Rise in BIM (Heins et al., 2021).....	32
Figure 2. 6 Research Framework	74
Figure 2. 7 Hypothesized model	76
Figure 3. 1 Exploratory sequential mixed methods research design.....	81
Figure 4. 1 CFA Model for BIM Adoption Indicators.....	137
Figure 4. 2 CFA Model for BIM Awareness	144
Figure 4. 3 SEM For the Effect of BIM Awareness (Concepts (C), Benefits (B), Standards and Roadmaps (SR), Project Phase (PP)) on BIM Adoption (BA)....	145
Figure 4. 4 CFA Model for the BIM Knowledge Indicators	152
Figure 4. 5 SEM for the effect of BIM Knowledge (<i>Fundamentals of BIM (F)</i> , <i>BIM Implementation in Projects (IP)</i> , <i>Training and Knowledge Acquisition in BIM (TK)</i> and <i>Advanced BIM Knowledge (ABK)</i>) on BIM Adoption (BA)	154
Figure 4. 6 CFA Model for the Organisational and Technological Readiness ...	164
Figure 4. 7 SEM for the effect of Organisational and Technological <i>Readiness (BIM Capability and Integration (BCI)</i> , <i>BIM Infrastructure and Skills Development (BISD)</i> and <i>BIM Leadership and Strategic Alignment (BLSA)</i> on BIM Adoption (BA)	166
Figure 4. 8 CFA Model for the Key Drivers Influencing BIM Adoption Indicators	174
Figure 4. 9 SEM for the effect of Key Drivers (KD) of BIM Adoption Construct on BIM Adoption (BA).....	175
Figure 4. 10 CFA Model for the Key Barriers Influencing BIM Adoption Indicators	182

Figure 4. 11 SEM for the Effect of the Identified Barriers to BIM Adoption in Ghana's construction industry on the extent of BIM Adoption	184
Figure 4. 12 CFA Model for the Impact of BIM on Construction Project Performance Indicators	192
Figure 4. 13 SEM for the effect of the BIM Adoption on the Performance of Construction Projects in Ghana.....	193
Figure 4. 14 CFA Model for the Strategies for Effective Adoption of BIM Indicators	203
Figure 5. 1 Proposed Framework for BIM Adoption in Ghana's Construction Industry	230

LIST OF APPENDICES

Appendix A: Statistics Tables.....	291
Appendix B: Survey Questionnaire	326
Appendix C: Interview Guide	340

REFERENCES

- Abbasnejad, B., Nepal, M. P., Mirhosseini, S. A., Moud, H. I., & Ahankoob, A. (2021). Modelling the key enablers of organizational building information modelling (BIM) implementation: An interpretive structural modelling (ISM) approach. *Journal of Information Technology in Construction*, 26, 974-1008.
- Abd Jamil, A. H., & Fathi, M. S. (2018). Contractual challenges for BIM-based construction projects: a systematic review. *Built Environment Project and Asset Management*, 8(4), 372-385. <https://doi.org/10.1108/BEPAM-12-2017-0131>
- Abd Jamil, A. H., & Fathi, M. S. (2020). Enhancing BIM-based information interoperability: Dispute resolution from legal and contractual perspectives. *Journal of construction engineering and management*, 146(7), 05020007.
- Abdalla, S. B., Rashid, M., Yahia, M. W., Mushtaha, E., Opoku, A., Sukkar, A., Maksoud, A., & Hamad, R. (2023). Comparative analysis of building information modeling (BIM) patterns and trends in the United Arab Emirates (UAE) with developed countries. *Buildings*, 13(3), 695.
- Abdallah, A., Doloi, H., & Holzer, D. (2023). Exploring the application of BIM in Tanzanian public sector projects using social network analysis. *Built Environment Project and Asset Management*, 13(4), 552-573.
- Abdirad, H., & Dossick, C. S. (2016). BIM curriculum design in architecture, engineering, and construction education: a systematic review. *Journal of Information Technology in Construction (ITcon)*, 21(17), 250-271.
- Abdullah, M. S., Salem, M., Said, S. O., & Tantawy, M. (2024). BIM Adoption in MENA's Construction Industry: A Contractor's Perspective. *Civil engineering journal*, 10(08).
- Abualdenien, J., & Borrmann, A. (2019). A meta-model approach for formal specification and consistent management of multi-LOD building models. *Advanced Engineering Informatics*, 40(2), 135-153.
- Abubakar, M., Ibrahim, Y., Kado, D., & Bala, K. (2014). Contractors' perception of the factors affecting Building Information Modelling (BIM) adoption in the Nigerian Construction Industry. In *Computing in civil and building engineering (2014)* (pp. 167-178).
- Acquah, I. S. K., Essel, D., Baah, C., Agyabeng-Mensah, Y., & Afum, E. (2021). Investigating the efficacy of isomorphic pressures on the adoption of green manufacturing practices and its influence on organizational legitimacy and financial performance. *Journal of Manufacturing Technology Management*, 32(7), 1399-1420.
- Acquah, R., Eyiah, A. K., & Oteng, D. (2018). Acceptance of building information modelling: A survey of professionals in the construction industry in Ghana. *Journal of Information Technology in Construction*, 23.
- Adam, V., Manu, P., Mahamadu, A.-M., Dziekonski, K., Kissi, E., Emuze, F., & Lee, S. (2021). Building information modelling (BIM) readiness of construction professionals: the context of the Seychelles construction industry. *Journal of Engineering, Design and Technology*, 20(3), 823-840.
- Addy, M., Adinyira, E., & Ayarkwa, J. (2018). Antecedents of building information modelling adoption among quantity surveyors in Ghana: An application of

- a technology acceptance model. *Journal of Engineering, Design and Technology*, 16(2). <https://doi.org/10.1108/JEDT-06-2017-0056>
- Addy, M. N., Dadzoe, F., Kwofie, T. E., Aigbavboa, C., & Simons, B. (2024). Innovative green construction adoption in Ghana: architects' perspectives from theory of planned behaviour. *Built Environment Project and Asset Management*, 14(5), 782-797.
- Addy, M. N., Kwofie, T. E. E., Agbonani, D. M., & Essegbey, A. E. (2023). Using the TOE theoretical framework to study the adoption of BIM-AR in a developing country: the case of Ghana. *Journal of Engineering, Design and Technology*, Vol. ahead-of-print (No. ahead-of-print). <https://doi.org/10.1108/JEDT-02-2022-0096>
- Adekunle, S. A., Ejohwomu, O., & Aigbavboa, C. O. (2021). Building information modelling diffusion research in developing countries: A user meta-model approach. In *Buildings* (Vol. 11): MDPI AG.
- Adewola, J. A., Mambo, A. D., & Adejumo, A. S. (2023). EXPLORING THE IMPLEMENTATION CHALLENGES OF ADOPTING BUILDING INFORMATION MODELLING (BIM) IN ABUJA, NIGERIA. *Nile Journal of Engineering and Applied Science*, 1(1), 0-0.
- Adinyira, E., Agyekum, K., Manu, P., Mahamadu, A.-M., & Olomolaiye, P. (2022). Lessening procurement deviations using procurement post reviews: evidence from Ghana. *Journal of Financial Management of property and Construction*, 27(2), 199-219.
- Afolabi, A., Amusan, L., Owolabi, D., Ojelabi, R., Joshua, O., & Tunji-Olayeni, P. (2018). Assessment of the linkages and leakages in a cloud-based computing collaboration among construction stakeholders. Construction Research Congress 2018: Construction Information Technology - Selected Papers from the Construction Research Congress 2018,
- Afzal, M. (2021). *BIM 7D: research on applications for operations & maintenance*
- Agyekum, A. K., Fugar, F. D. K., Agyekum, K., Akomea-Frimpong, I., & Pittri, H. (2023). Barriers to stakeholder engagement in sustainable procurement of public works. *Engineering, construction and architectural management*, 30(9), 3840-3857.
- Agyekum, K., Adinyira, E., Baiden, B., Ampratwum, G., & Duah, D. (2019). Barriers to the adoption of green certification of buildings: A thematic analysis of verbatim comments from built environment professionals. *Journal of Engineering, Design and Technology*, 17(5), 1035-1055.
- Ahadzie, D., Proverbs, D., & Sarkodie-Poku, I. (2014). Competencies required of project managers at the design phase of mass house building projects. *International journal of project management*, 32(6), 958-969.
- Ahankoob, A., Abbasnejad, B., & Wong, P. S. (2020). The support of continuous information flow through building information modeling (BIM). The 10th International Conference on Engineering, Project, and Production Management,
- Ahmed, A. L., & Kassem, M. (2018). A unified BIM adoption taxonomy: Conceptual development, empirical validation and application. *Automation in Construction*, 96, 103-127.

- Ahmed, S. (2018). Barriers to implementation of building information modeling (BIM) to the construction industry: a review. *Journal of civil engineering and construction*, 7(2), 107-113.
- Ahmed, Y. A., Shehzad, H. M. F., Khurshid, M. M., Abbas Hassan, O. H., Abdalla, S. A., & Alrefai, N. (2022). Examining the effect of interoperability factors on building information modelling (BIM) adoption in Malaysia. *Construction innovation*.
- Ahola, T. (2023). *On the Synchronisation of Activities During Construction Projects*.
- Ahuja, R., Sawhney, A., Jain, M., Arif, M., & Rakshit, S. (2020). Factors influencing BIM adoption in emerging markets—the case of India. *International Journal of Construction Management*, 20(1), 65-76.
- Aigbavboa, C., Ebekozi, A., Afetorgbor, E. K., Arthur-Aidoo, B. M., & Thwala, W. D. (2024). Investigating the barriers facing corporate social responsibility in the built environment: Ghana's perspective from a qualitative approach. *Property Management*, 42(4), 493-506.
- Ajgaonkar, S., Neelam, N. G., & Wiemann, J. (2022). Drivers of workforce agility: a dynamic capability perspective. *International Journal of Organizational Analysis*, 30(4), 951-982.
- Akwaah, G. (2015a). *Guideline for building the capacity of contractors for adoption and implementation of building information modeling (BIM) in Ghana*
- Akwaah, G. (2015b). Guideline for building the capacity of contractors for adoption and implementation of building information modeling (BIM) in Ghana. <http://oatd.org/oatd/record?record=oai%5C%3Ahttp%5C%3A%5C%2F%5C%2Ffir.knust.edu.gh%5C%3A123456789%5C%2F8086>
- Al-Mohammad, M. S., Haron, A. T., Esa, M., Aloko, M. N., Alhammedi, Y., Anandh, K., & Rahman, R. A. (2022). Factors affecting BIM implementation: Evidence from countries with different income levels. *Construction innovation*, 23(3), 683-710.
- Al-Yami, A., & Sanni-Anibire, M. O. (2021). BIM in the Saudi Arabian construction industry: State of the art, benefit and barriers. *International Journal of Building Pathology and Adaptation*, 39(1), 33-47.
- Al Shanto, A., Ananta, A. F., Rahman, M., & Manjur, K. A. (2024). Bim in Bangladesh's Education System and Construction Industry: Adaptability And Benefits in A Developing Country Context. 7th International Conference on Civil Engineering for Sustainable Development (ICCESD 2024),
- Alam, F., Ali, J., Madni, S., & Husnain, H. A. (2023). Identifying Barriers to Effective BIM Adoption in the Re-Engineering of Construction Business Practices in Developing Countries.
- Alazmeh, N., Underwood, J., & Coates, P. (2018). Implementing a BIM collaborative workflow in the UK construction market. *Building Information Systems in the Construction Industry*, 25.
- Allmendinger, P., & Sielker, F. (2018). Centre for Digital Built Britain Mini-Projects Programme 2017–18 Urban Planning and BIM Final Report. *University of Cambridge, UK*.

- Almarri, K., Aljarman, M., & Boussabaine, H. (2019). Emerging contractual and legal risks from the application of building information modelling. *Engineering, construction and architectural management*, 26(10), 2307-2325.
- Almarri, K., Aljarman, M., & Boussabaine, H. (2021). Emerging managerial risks from the application of building information modelling. *Journal of Facilities Management*, 19(2), 228-248.
- Alreshidi, E., Mourshed, M., & Rezgui, Y. (2017). Factors for effective BIM governance. *Journal of Building Engineering*, 10, 89-101.
- Altohami, A. B. A., Haron, N. A., Ales@ Alias, A. H., & Law, T. H. (2021). Investigating approaches of integrating BIM, IoT, and facility management for renovating existing buildings: A review. *Sustainability*, 13(7), 3930.
- Ametepey, S. O., Ansah, S., & Gyadu-Asiedu, W. (2020). Strategies for sustainable environmental management of construction activities in Ghana. *Journal of Building Construction and Planning Research*, 8(03), 180.
- Ameyaw, C., Abaitey, B. A., Mensah, S., & Manu, E. (2021). Assessing the cost of competitive tendering in Ghana using transaction cost theory. *Built Environment Project and Asset Management*, 11(5), 835-850.
- Amudjie, J., Agyekum, K., Adinyira, E., Amos-Abanyie, S., & Kumah, V. M. A. (2023). Awareness and practice of the principles of circular economy among built environment professionals. *Built Environment Project and Asset Management*, 13(1), 140-156.
- Anaman, K. A., & Osei-Amponsah, C. (2007). Analysis of the causality links between the growth of the construction industry and the growth of the macroeconomy in Ghana. *Construction management and economics*, 25(9). <https://doi.org/10.1080/01446190701411208>
- Andersson, R., & Eidenskog, M. (2023). Beyond barriers—exploring resistance towards BIM through a knowledge infrastructure framework. *Construction management and economics*, 1-16.
- Annex, A., & Rules, C. (2015). National BIM Standard-United States® Version 3. In.
- Appiah, B. L. (2020a). Assessment of Building Information Modeling (BIM) Awareness, Knowledge and Its Adoption in the Ghanaian Construction Industry. *Journal of Civil, Construction and Environmental Engineering*, 5(6), 138-150.
- Appiah, B. L. (2020b). Assessment of Building Information Modeling (BIM) Awareness, Knowledge and Its Adoption in the Ghanaian Construction Industry. *Journal of Civil, Construction and Environmental Engineering*, 5(6). <https://doi.org/10.11648/j.jccee.20200506.11>
- Arayici, Y., & Aouad, G. (2010). Building information modelling (BIM) for construction lifecycle management. *Construction and Building: Design, Materials, and Techniques*, 2010, 99-118.
- Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., & O'reilly, K. (2011a). BIM adoption and implementation for architectural practices. *Structural survey*, 29(1), 7-25.
- Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., & O'Reilly, K. (2011b). Technology adoption in the BIM implementation for lean architectural practice. *Automation in construction*, 20(2), 189-195.

- Armah, N. N. O. (2015). Assessing the Benefits and Barriers of the use of BIM in the Ghanaian Construction Industry. *Unpublished Thesis in Construction Management. Kwame Nkrumah University of Science and Technology, Kumasi.*
- Asamoah, D., Annan, J., Rockson, S. B., & Effah-Baah, D. (2019). The influence of the status quo bias theory in the compliance to public procurement regulations in a Sub-Saharan economy. *International Journal of Procurement Management*, 12(1), 15-40.
- Asare, K. A., Ruikar, K. D., Zanni, M., & Soetanto, R. (2020). BIM-based LCA and energy analysis for optimised sustainable building design in Ghana. *SN Applied Sciences*, 2(1), 1-20.
- Ashworth, R., Boyne, G., & Delbridge, R. (2009). Escape from the iron cage? Organizational change and isomorphic pressures in the public sector. *Journal of public administration research and theory*, 19(1), 165-187.
- Asiedu, R. O., & Adaku, E. (2020). Cost overruns of public sector construction projects: a developing country perspective. *International Journal of Managing Projects in Business*, 13(1), 66-84.
- Assensoh-Kodua, A. (2019). The resource-based view: A tool of key competency for competitive advantage. *Problems and Perspectives in Management*, 17(3), 143.
- Authority, B. C. (2013). Technology adoption: Building Information Model (BIM) Fund. *Building Construction Authority*. Retrieved from <http://www.bca.gov.sg/BIM/bimfund.html>.
- Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and Management in Engineering*, 11(3). [https://doi.org/10.1061/\(ASCE\)LM.1943-5630.0000127](https://doi.org/10.1061/(ASCE)LM.1943-5630.0000127)
- Azhar, S., & Behringer, A. (2013). A BIM-based approach for communicating and implementing a construction site safety plan. Proc., 49th ASC Annual International Conference Proceedings,
- Azhar, S., Khalfan, M., & Maqsood, T. (2012). Building information modeling (BIM): now and beyond. *Australasian Journal of Construction Economics and Building, The*, 12(4), 15-28. <https://doi.org/10.5130/ajceb.v12i4.3032>
- Aziz, N. M., & Zainon, N. (2022). Driving factors for lean-BIM implementation in Malaysia's construction industry: qualitative interview-based study. *Smart and Sustainable Built Environment*(ahead-of-print).
- Babatunde, S. O., Ekundayo, D., Adekunle, A. O., & Bello, W. (2020). Comparative analysis of drivers to BIM adoption among AEC firms in developing countries: a case of Nigeria. *Journal of Engineering, Design and Technology*, 18(6), 1425-1447.
- Babatunde, S. O., Udejaja, C., & Adekunle, A. O. (2021). Barriers to BIM implementation and ways forward to improve its adoption in the Nigerian AEC firms. *International Journal of Building Pathology and Adaptation*, 39(1), 48-71. <https://doi.org/10.1108/IJBPA-05-2019-0047>
- Badrinath, A. C., Chang, Y.-T., & Hsieh, S.-H. (2016). An overview of global research trends in BIM from analysis of BIM publications. 16th international conference on computing in civil and building engineering, ICCCBE,

- Baharuddin, B., & Yusof, M. M. (2018). Evaluation of risk management practices in information systems project in the public sector. *Jurnal Pengurusan*, 53(2), 1-20.
- Bamfo-Agyei, E., & Nani, G. (2015). The adoption of Building information modeling (BIM) for procurement of works in Ghana. *AFRICAN JOURNAL OF APPLIED RESEARCH*, 2(2).
- Bamgbose, O. A., Ogunbayo, B. F., & Aigbavboa, C. O. (2024). Barriers to Building information modelling adoption in small and medium enterprises: Nigerian construction industry perspectives. *Buildings*, 14(2), 538.
- Banihashemi, S., Golizadeh, H., & Rahimian, F. P. (2022). *Data-driven BIM for Energy Efficient Building Design*. Taylor & Francis.
- Bao, Z., Laovisutthichai, V., Tan, T., Wang, Q., & Lu, W. (2022). Design for manufacture and assembly (DfMA) enablers for offsite interior design and construction. *Building Research & Information*, 50(3), 325-338.
- Barajei, C., Appiah-Kubi, E., Kheni, N. A., Yalley, P. P., & Iddrisu, W. (2023). Success factors of pre-construction stages of Ghanaian public road construction project life cycle. *International Journal of Construction Management*(2), 1-10.
- Barajei, C., Kheni, N. A., Appiah-Kubi, E., Danso, H., & Iddrisu, A. W. (2023). Enhancing the success of Ghanaian public road construction projects. *Cogent Engineering*, 10(1), 2199514.
- Barkokebas, B., Khalife, S., Al-Hussein, M., & Hamzeh, F. (2021). A BIM-lean framework for digitalisation of premanufacturing phases in offsite construction. *Engineering, construction and architectural management*, 28(8), 2155-2175.
- Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM—A case study approach. *Automation in Construction*, 24, 149-159.
- Barney, J. B. (2001). Resource-based theories of competitive advantage: A ten-year retrospective on the resource-based view. *Journal of management*, 27(6), 643-650.
- Barney, J. B., Ketchen Jr, D. J., & Wright, M. (2021). Resource-based theory and the value creation framework. *Journal of Management*, 47(7), 1936-1955.
- Bazeley, P. (2018). Mixed methods in my bones”: Transcending the qualitative-quantitative divide. *International Journal of multiple research approaches*, 10(1), 334-341.
- Becerik-Gerber, B., Gerber, D. J., & Ku, K. (2011). The pace of technological innovation in architecture, engineering, and construction education: integrating recent trends into the curricula.
- Belay, S., Goedert, J., Woldesenbet, A., & Rokooei, S. (2021a). Comparison of BIM adoption models between public and private sectors through empirical investigation. *Advances in Civil Engineering*, 2021(1), 5577654.
- Belay, S., Goedert, J., Woldesenbet, A., & Rokooei, S. (2021b). Enhancing BIM implementation in the Ethiopian public construction sector: an empirical study. *Cogent Engineering*, 8(1), 1886476-1886476.
- Bernegger, H. J., Laube, P., Ochsner, P., Meslec, M., Rahn, H., Junghardt, J., Aurich, I., & Ashworth, S. (2022). A new method combining BIM and GIS data to optimise the sustainability of new construction projects in Switzerland. *IOP Conference Series: Earth and Environmental Science*,

- Bhattacharya, S., & Momaya, K. (2021). Actionable strategy framework for digital transformation in AECO industry. *Engineering, construction and architectural management*, 28(5), 1397-1422.
- Biagini, C., Capone, P., Donato, V., & Facchini, N. (2016). Towards the BIM implementation for historical building restoration sites. *Automation in Construction*, 71, 74-86.
- Bin, A. (2023). A Study on the Building Information Modeling (BIM) Adoption among Construction Companies in China: A One Belt One Road Critical Success Approach. *Journal of Digitainability, Realism & Mastery (DREAM)*, 2(01), 20-27.
- Boadu, E. F., Wang, C. C., & Sunindijo, R. Y. (2020). Characteristics of the construction industry in developing countries and its implications for health and safety: An exploratory study in ghana. *International Journal of Environmental Research and Public Health*, 17(11), 1-21. <https://doi.org/10.3390/ijerph17114110>
- Boakye, A., Nwabufo, N., & Dinbabo, M. (2022). The impact of technological progress and digitization on Ghana's economy. *African Journal of Science, Technology, Innovation and Development*, 14(7), 1981-1986.
- Boamah, F. A., Zhang, J., Wen, D., Sherani, M., Hayat, A., & Horbanenko, O. (2022). Enablers of knowledge management: practical research-based in the construction industry. *International Journal of Innovation Science*, 14(1), 121-137.
- Boateng, E. A., Fage, J. D., & Davies, O. (2006). *Ghana*. Britannica. Retrieved 21/05/2023 from <https://www.britannica.com/place/Ghana>
- Borrmann, A., König, M., Koch, C., & Beetz, J. (2018). *Building information modeling: Why? what? how?* Springer.
- Brinkmann, S., & Kvale, S. (2015). *Interviews: Learning the craft of qualitative research interviewing*. Sage publications.
- Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modelling (BIM). *International journal of project management*, 31(7), 971-980.
- Buertey, J., Kumi, T., Astrim, F., & Boateng, K. (2015). Managing the drivers of cost escalation in the Road Development Sector: An Overview. *Int. J. Sci. Technol. Soc*, 3, 295.
- Byrne, B. M. (2013). *Structural equation modeling with Mplus: Basic concepts, applications, and programming*. routledge.
- Camngca, V. P., Amoah, C., & Ayesu-Koranteng, E. (2022). Underutilisation of information communication and technology in the public sector construction project's implementation. *Journal of Facilities Management*.
- Cao, D., Li, H., & Wang, G. (2017). Impacts of building information modeling (BIM) implementation on design and construction performance: A resource dependence theory perspective. *Frontiers of Engineering Management*, 4(1), 20-34.
- Chan, A. P. C., Darko, A., Olanipekun, A. O., & Ameyaw, E. E. (2018). Critical barriers to green building technologies adoption in developing countries: The case of Ghana. *Journal of cleaner production*, 172, 1067-1079.
- Chan, D. W. M., Olawumi, T. O., & Ho, A. M. L. (2019). Perceived benefits of and barriers to Building Information Modelling (BIM) implementation in

- construction: The case of Hong Kong. *Journal of Building Engineering*, 25, 100764-100764.
- Chaurasia, S. S., & Verma, S. (2020). Strategic determinants of big data analytics in the AEC sector: A multi-perspective framework. *Construction Economics and Building*, 20(4), 63-81.
- Chen, G., Chen, J., Tang, Y., Li, Q., & Luo, X. (2022). Identifying effective collaborative behaviors in building information modeling-enabled construction projects. *Journal of construction engineering and management*, 148(6), 04022026.
- Chen, K., Lu, W., & Wang, J. (2020). University-industry collaboration for BIM education: Lessons learned from a case study. *Industry and Higher Education*, 34(6), 401-409.
- Chen, X., Chang-Richards, A., Ling, F. Y. Y., Yiu, T. W., Pelosi, A., & Yang, N. (2023). Developing a readiness model and a self-assessment tool for adopting digital technologies in construction organizations. *Building Research & Information*, 51(3), 241-256.
- Cheng, J. C. P., & Lu, Q. (2015). A review of the efforts and roles of the public sector for BIM adoption worldwide. In *Journal of Information Technology in Construction* (Vol. 20).
- Chew, M. Y. L., Teo, E. A. L., Shah, K. W., Kumar, V., & Hussein, G. F. (2020). Evaluating the roadmap of 5G technology implementation for smart building and facilities management in Singapore. *Sustainability*, 12(24), 10259.
- Chong, H.-Y., Fan, S.-L., Sutrisna, M., Hsieh, S.-H., & Tsai, C.-M. (2017). Preliminary contractual framework for BIM-enabled projects. *Journal of construction engineering and management*, 143(7), 04017025.
- Ciullo, A. (2024). Effects of BIM adoption to a construction company's internationalization in Asian markets.
- Clarke, V., & Braun, V. (2013). Teaching thematic analysis: Overcoming challenges and developing strategies for effective learning. *The psychologist*, 26(2), 120-123.
- Cobbinah, P. B., & Erdiaw-Kwasie, M. O. (2018). Urbanization in Ghana: Insights and implications for urban governance. In *E-planning and collaboration: Concepts, methodologies, tools, and applications* (pp. 256-278). IGI Global.
- Cohen, L., Manion, L., & Morrison, K. (2013). Validity and reliability. In *Research methods in education* (pp. 203-240). Routledge.
- Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Pearson Education, Inc.
- Creswell, J. W. (2014). *A concise introduction to mixed methods research*. SAGE publications.
- Creswell, J. W. (2015). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. pearson.
- Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.
- Cristobal, E., Flavian, C., & Guinaliu, M. (2007). Perceived e-service quality (PeSQ) measurement validation and effects on consumer satisfaction and web site loyalty. *Managing service quality: An international journal*, 17(3), 317-340.

- da Silva, T. F. L., de Carvalho, M. M., & Vieira, D. R. (2022). BIM critical-success factors in the design phase and risk management: Exploring knowledge and maturity mediating effect. *Journal of construction engineering and management*, 148(10), 04022104.
- Dadzie, C. A., Winston, E. M., & Dadzie, K. Q. (2012). Organizational culture, competitive strategy, and performance in Ghana. *Journal of African Business*, 13(3), 172-182.
- Dakhil, A., Underwood, J., & Alshawhi, M. (2019). Critical success competencies for the BIM implementation process: UK construction clients. *Journal of Information Technology in Construction (ITcon)*, 24.
- Darko, A., & Chan, A. P. C. (2018). Strategies to promote green building technologies adoption in developing countries: The case of Ghana. *Building and Environment*, 130, 74-84.
- Darko, E., & Löwe, A. (2016). *Ghana's construction sector and youth employment*. Overseas Development Institute.
- Datta, S. D., Tayeh, B. A., Hakeem, I. Y., & Abu Aisheh, Y. I. (2023). Benefits and Barriers of Implementing Building Information Modeling Techniques for Sustainable Practices in the Construction Industry—A Comprehensive Review. *Sustainability*, 15(16), 12466.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 319-340.
- Deng, H., Ou, Z., Zhang, G., Deng, Y., & Tian, M. (2021). BIM and computer vision-based framework for fire emergency evacuation considering local safety performance. *Sensors*, 21(11), 3851.
- Devarakonda, E. K. (2021). *An Acceptable Cloud Computing Model for Public Sectors* [Walden University].
- DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American sociological review*, 147-160.
- Ding, Z., Zuo, J., Wu, J., & Wang, J. (2015). Key factors for the BIM adoption by architects: A China study. *Engineering, construction and architectural management*, 22(6), 732-748.
- Doukari, O., Kassem, M., & Greenwood, D. (2023). Building Information Modelling. In *Disrupting Buildings: Digitalisation and the Transformation of Deep Renovation* (pp. 39-51). Springer.
- Doukari, O., Seck, B., & Greenwood, D. (2022). The creation of construction schedules in 4D BIM: a comparison of conventional and automated approaches. *Buildings*, 12(8), 1145-1145.
- Doumbouya, L., Gao, G., & Guan, C. (2016). Adoption of the Building Information Modeling (BIM) for construction project effectiveness: The review of BIM benefits. *American Journal of Civil Engineering and Architecture*, 4(3), 74-79.
- Dowsett, R. M., & Harty, C. F. (2019). Assessing the implementation of BIM—an information systems approach. *Construction management and economics*, 37(10), 551-566.
- Durdyev, S., Ashour, M., Connelly, S., & Mahdiyar, A. (2022). Barriers to the implementation of Building Information Modelling (BIM) for facility

- management. *Journal of Building Engineering*, 46(4), 103736.
<https://doi.org/https://doi.org/10.1016/j.jobbe.2021.103736>
- Durdyev, S., Mbachu, J., Thurnell, D., Zhao, L., & Hosseini, M. R. (2021). BIM adoption in the Cambodian construction industry: key drivers and barriers. *ISPRS International Journal of Geo-Information*, 10(4), 215-215.
- Eadie, R., Odeyinka, H., Browne, M., Mahon, C., & Yohanis, M. (2014). Building information modelling adoption: an analysis of the barriers of implementation. *Journal of Engineering and Architecture*, 2(1), 77-101.
- Eastman, C. M. (2011a). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors*. John Wiley & Sons.
- Eastman, C. M. (2011b). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors* (Vol. 1-196). John Wiley & Sons.
- Eastman, C. M., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors*. John Wiley & Sons.
- Economics, O. (2021). Future of construction: A global forecast for construction to 2030. *Marsh & Guy Carpenter Oxford Economics*.
- Edu-Buandoh, D. (2016). Identity and representation through language in Ghana: The postcolonial self and the other. *International Journal of Society, Culture & Language*, 4(1 (Special Issue on African Cultures and Languages)), 34-44.
- Egwim, C. N., Alaka, H., Demir, E., Balogun, H., & Ajayi, S. (2023). Systematic review of critical drivers for delay risk prediction: Towards a conceptual framework for BIM-based construction projects. *Frontiers in Engineering and Built Environment*, 3(1), 16-31.
- El Hajj, C., Martínez Montes, G., & Jawad, D. (2021). An overview of BIM adoption barriers in the Middle East and North Africa developing countries. *Engineering, construction and architectural management*.
<https://doi.org/10.1108/ECAM-05-2021-0432>
- El Hajj, C., Martínez Montes, G., & Jawad, D. (2023). An overview of BIM adoption barriers in the Middle East and North Africa developing countries. *Engineering, construction and architectural management*, 30(2), 889-913.
- Elghaish, F., Matarneh, S., Talebi, S., Kagioglou, M., Hosseini, M. R., & Abrishami, S. (2021). Toward digitalization in the construction industry with immersive and drones technologies: a critical literature review. *Smart and Sustainable Built Environment*, 10(3), 345-363.
- Emmanuel, I., Danquah, E. O., Ukpoju, E. A., Obasa, J., & Motilola, T. (2024). Use of Building Information Modeling (BIM) to Improve Construction Management in the USA.
- Emmitt, S. (2016). BIM and the Future of Design Management. *Construction manager's Bim handbook*, 123-123.
- Evans, M., Farrell, P., Elbeltagi, E., & Dion, H. (2023). Barriers to integrating lean construction and integrated project delivery (IPD) on construction megaprojects towards the global integrated delivery (GID) in multinational organisations: lean IPD&GID transformative initiatives. *Journal of Engineering, Design and Technology*, 21(3), 778-818.

- Evans, M., Farrell, P., Mashali, A., & Zewein, W. (2021). Critical success factors for adopting building information modelling (BIM) and lean construction practices on construction mega-projects: A Delphi survey. *Journal of Engineering, Design and Technology*, 19(2), 537-556.
- Evans, Y., & Antwi, A. V. (2019). China's Outward Foreign Direct Investment in Africa: How are Ghana Benefiting and its Issues on the Economy? *Economy*, 6(1), 34-40.
- Fan, S.-L., Lee, C.-Y., Chong, H.-Y., & Skibniewski, M. J. (2018). A critical review of legal issues and solutions associated with building information modelling. *Technological and Economic Development of Economy*, 24(5), 2098-2130.
- Fatt, C. T. (2011). BIM Road Map For Singapore Construction Industry. *BIM Journal*.
- Field, A. (2005). Exploratory factor analysis. *Discovering statistics using SPSS*, 619-680.
- Flick, U. (2015). *Introducing research methodology: A beginner's guide to doing a research project*. Sage.
- Forgues, E.-C., Carignan, V., Forgues, D., & Rajeb, S. B. (2016). A framework for improving collaboration patterns in BIM projects. Cooperative Design, Visualization, and Engineering: 13th International Conference, CDVE 2016, Sydney, NSW, Australia, October 24–27, 2016, Proceedings 13,
- Franz, B., Leicht, R., Molenaar, K., & Messner, J. (2017). Impact of team integration and group cohesion on project delivery performance. *Journal of construction engineering and management*, 143(1), 04016088-04016088.
- Gamil, Y., & Rahman, I. A. R. (2019). Awareness and challenges of building information modelling (BIM) implementation in the Yemen construction industry. *Journal of Engineering, Design and Technology*, 17(5), 1077-1084.
- Ganbat, T., Chong, H.-Y., & Liao, P.-C. (2020). Mapping BIM uses for risk mitigation in international construction projects. *Advances in Civil Engineering*, 2020(1), 5143879.
- Georgiadou, M. C. (2019). An overview of benefits and challenges of building information modelling (BIM) adoption in UK residential projects. *Construction innovation*, 19(3), 298-320.
- Gerges, M., Austin, S., Mayouf, M., Ahiakwo, O., Jaeger, M., Saad, A., & El Gohary, T. (2017). An investigation into the implementation of Building Information Modeling in the Middle East. *Journal of Information Technology in Construction*, 22, 1-15.
- Ghana Statistical, S. (2016). 2015 Labour force report. *Labour force survey*.
- Ghana Statistical Service, G. (2012). *2010 population and housing census report* (Vol. 1). Ghana Statistical Service.
- Ghana Statistical Service, G. (2021). *2021 Population Housing Census. Provisional results* (1682-1750).
- Gholami, Y. (2023). *Investigating adoption of digital technologies in construction projects*. Linkopings Universitet (Sweden).
- Ghosh, A., Parrish, K., & Chasey, A. D. (2015). Implementing a vertically integrated BIM curriculum in an undergraduate construction management

- program. *International Journal of Construction Education and Research*, 11(2), 121-139.
- Gidigah, B. K., Agyekum, K., & Baiden, B. K. (2024). Evaluating the challenges of implementing social value in the procurement of construction works. *Journal of Responsible Production and Consumption*, 1(1), 206-228.
- Giel, B., & Issa, R. (2014). Framework for evaluating the BIM competencies of building owners. In *Computing in Civil and Building Engineering (2014)* (pp. 552-559).
- Girginkaya Akdag, S., & Maqsood, U. (2020). A roadmap for BIM adoption and implementation in developing countries: the Pakistan case. *Archnet-IJAR: International Journal of Architectural Research*, 14(1), 112-132. <https://doi.org/10.1108/ARCH-04-2019-0081>
- Girya, L., & Romanov, K. (2022). Possibilities of BIM and GIS in the system for assessing the sustainability of the urban environment. AIP Conference Proceedings,
- GSA. (2024). *3D-4D building information modeling* U.S. General Services Administration. Retrieved 29/03/2024 from <https://www.gsa.gov/real-estate/design-and-construction/3d4d-building-information-modeling?gsaredirect=bim>
- GSS. (2021). *Intergrated Business Establishment Survey (IBES)*, Ghana (1368-3047).
- Guo, K., Li, Q., Zhang, L., & Wu, X. (2021). BIM-based green building evaluation and optimization: A case study. *Journal of cleaner production*, 320, 128824.
- Gurgun, A. P., Koc, K., & Kunkcu, H. (2022). Exploring the adoption of technology against delays in construction projects. *Engineering, Construction and Architectural Management*, ahead-of-print(ahead-of-print). <https://doi.org/https://doi.org/10.1108/ECAM-06-2022-0566>
- Guribie, F. L., Kheni, N. A., & Sule, M. (2022). Structural equation modeling of the critical driving forces of offsite construction in Ghana. *Built Environment Project and Asset Management*, 12(4), 667-683.
- Hadzaman, N. A. H., Takim, R., & Nawawi, A. H. (2015). BIM roadmap strategic implementation plan: Lesson learnt from Australia, Singapore and Hong Kong. Proceedings in 31st annual ARCOM conference,
- Hair Jr, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., Ray, S., Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2021). An introduction to structural equation modeling. *Partial least squares structural equation modeling (PLS-SEM) using R: a workbook*, 1-29.
- Hajirasouli, A., Banihashemi, S., Sanders, P., & Rahimian, F. (2023). BIM-enabled virtual reality (VR)-based pedagogical framework in architectural design studios. *Smart and Sustainable Built Environment*, ahead-of-print(ahead-of-print). [https://doi.org/ https://doi.org/10.1108/SASBE-07-2022-0149](https://doi.org/https://doi.org/10.1108/SASBE-07-2022-0149)
- Hallstedt, S., & Pigosso, D. (2017). Sustainability integration in a technology readiness assessment framework. DS 87-5 Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 5: Design for X, Design to X, Vancouver, Canada, 21-25.08. 2017,
- Hamma-adama, M., & Kouider, T. (2019). Comparative Analysis of BIM Adoption Efforts by Developed Countries as Precedent for New Adopter Countries.

Current Journal of Applied Science and Technology.
<https://doi.org/10.9734/cjast/2019/v36i230224>

- Hamma-adama, M., & Kouider, T. (2020). Macro-BIM Adoption Study: Establishing Nigeria's BIM Maturity. In *The Construction Industry in the Fourth Industrial Revolution*. https://doi.org/10.1007/978-3-030-26528-1_40
- Hannele, K., Reijo, M., Tarja, M., Sami, P., Jenni, K., & Teija, R. (2012). Expanding uses of building information modeling in life-cycle construction projects. *Work*, 41(Supplement 1), 114-119.
- Harris, F., McCaffer, R., Baldwin, A., & Edum-Fotwe, F. (2021). *Modern construction management*. John Wiley & Sons.
- Hassan, A. M., Negash, Y. T., & Hanum, F. (2024). An assessment of barriers to digital transformation in circular construction: An application of stakeholder theory. *Ain Shams Engineering Journal*, 15(7), 102787.
- Heins, C., Grunwald, G., & Helmus, M. (2021). Gamification and BIM The didactic guidance of decentralised interactions of a real-life BIM business game for higher education. ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction,
- Hong, Y., Hammad, A. W., Sepasgozar, S., & Akbarnezhad, A. (2019). BIM adoption model for small and medium construction organisations in Australia. *Engineering, construction and architectural management*, 26(2), 154-183.
- Hooper, M. (2015). BIM standardisation efforts-the case of Sweden. *Journal of Information Technology in Construction*, 20, 332-346.
- Howard, R., Restrepo, L., & Chang, C.-Y. (2017). Addressing individual perceptions: An application of the unified theory of acceptance and use of technology to building information modelling. *International journal of project management*, 35(2), 107-120.
- Hsia, J.-W., Chang, C.-C., & Tseng, A.-H. (2014). Effects of individuals' locus of control and computer self-efficacy on their e-learning acceptance in high-tech companies. *Behaviour & Information Technology*, 33(1), 51-64.
- Hu, L. t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal*, 6(1), 1-55.
- Huang, F., Teo, T., & Scherer, R. (2022). Investigating the antecedents of university students' perceived ease of using the Internet for learning. *Interactive learning environments*, 30(6), 1060-1076.
- Huang, S.-F., Chen, C.-S., & Dzung, R.-J. (2011). Design of track alignment using building information modeling. *Journal of Transportation Engineering*, 137(11), 823-830.
- Huang, Y. (2018). A Review of Approaches and Challenges of BIM Education in Construction Management. *Journal of Civil Engineering and Architecture*, 12(6), 401-407. <https://doi.org/10.17265/1934-7359/2018.06.001>
- Hussin, A. A., & Omran, A. (2009). Roles of professionals in construction industry. The International Conference on Economics and Administration, Faculty of Administration and Business, University of Bucharest, Romania ICEA-FAA Bucharest,

- Ibrahim, H. S., Hashim, N., & Jamal, K. A. A. (2019). The potential benefits of building information modelling (BIM) in construction industry. IOP Conference Series: Earth and Environmental Science,
- International Trade Administration. (2023). *Ghana - Construction and Infrastructure Industry*. International Trade Administration. Retrieved 23/01/2024 from <https://www.trade.gov/country-commercial-guides/ghana-construction-and-infrastructure-industry>
- Işık, Z., Arayıcı, Y., Aladağ, H., Demirdöğen, G., & Khosrowshahi, F. (2021). BIM, sustainability and energy optimization. *BIM Teaching and Learning Handbook: Implementation for Students and Educators*, 92.
- Ismail, N. A. A., Adnan, H., & Bakhary, N. A. (2019). Building Information Modelling (BIM) adoption by quantity surveyors: A preliminary survey from Malaysia. IOP Conference Series: Earth and Environmental Science,
- Ivankova, N. V., & Creswell, J. W. (2009). Mixed methods. *Qualitative research in applied linguistics: A practical introduction*, 23, 135-161.
- Jamal, K. A. A., Mohammad, M. F., Hashim, N., Mohamed, M. R., & Ramli, M. A. (2019). Challenges of Building Information Modelling (BIM) from the Malaysian architect's perspective. MATEC web of conferences,
- Jiang, R., Wu, C., Lei, X., Shemery, A., Hampson, K. D., & Wu, P. (2022). Government efforts and roadmaps for building information modeling implementation: Lessons from Singapore, the UK and the US. *Engineering, construction and architectural management*, 29(2), 782-818.
- Jung, W., & Lee, G. (2015). The Status of BIM Adoption on Six Continents. *International Journal of Civil, Structural, Construction and Architectural Engineering*, 9(5).
- Kadam, P., & Bhalerao, S. (2010). Sample size calculation. *International journal of Ayurveda research*, 1(1), 55-67.
- Kahsay, D. T., Salanterä, S., Tommila, M., Liukas, T., Rosio, R., Diji, A. K.-A., & Peltonen, L.-M. (2023). User Needs and Factors Associated With the Acceptability of Audiovisual Feedback Devices for Chest Compression Monitoring in Cardiopulmonary Resuscitation. *CIN: Computers, Informatics, Nursing*, 10.1097.
- Kaneta, T., Furusaka, S., Tamura, A., & Deng, N. (2016). Overview of BIM implementation in Singapore and Japan. *Journal of Civil Engineering and Architecture*, 10(12), 1305-1312.
- Kassem, M., & Succar, B. (2017a). Macro BIM adoption: Comparative market analysis. *Automation in Construction*, 81. <https://doi.org/10.1016/j.autcon.2017.04.005>
- Kassem, M., & Succar, B. (2017b). Macro BIM adoption: Comparative market analysis. *Automation in Construction*, 81, 286-299.
- Kepher¹, J. A., Rambo¹, C. M., & Nyonje, R. O. (2021). Subcontractor Oversight on Construction Cost Overruns in Real Estate Projects in Nairobi and Kisumu Counties, Kenya. *Journal of Sustainable Development*, 14(6).
- Keung, C. C. W., Yiu, T. W., & Feng, Z. (2023). Building information modeling education for quantity surveyors in Hong Kong: current states, education gaps, and challenges. *International Journal of Construction Education and Research*, 19(3), 259-275.

- Khoshfetrat, R., Sarvari, H., Chan, D. W., & Rakhshanifar, M. (2022). Critical risk factors for implementing building information modelling (BIM): a Delphi-based survey. *International Journal of Construction Management*, 22(12), 2375-2384.
- Khudhair, A., Li, H., Ren, G., & Liu, S. (2021). Towards future BIM technology innovations: A bibliometric analysis of the literature. *Applied Sciences*, 11(3), 1232.
- Kipo-Sunyezi, D. D., Abubakari, A.-F., & Banchani, J.-P. S. (2024). Public procurement policies of Nigeria and Ghana: an analysis of the administrative challenges in achieving value for money. *Journal of Public Procurement*, 24(2), 193-209.
- Kissi, E., Aigbavboa, C., & Kuoribo, E. (2022). Emerging technologies in the construction industry: challenges and strategies in Ghana. *Construction innovation*. <https://doi.org/10.1108/CI-11-2021-0215>
- Kline, R. B. (2010). Promise and pitfalls of structural equation modeling in gifted research.
- Kline, R. B. (2023). *Principles and practice of structural equation modeling*. Guilford publications.
- Koseoglu, O., Keskin, B., & Ozorhon, B. (2019). Challenges and enablers in BIM-enabled digital transformation in mega projects: The Istanbul new airport project case study. *Buildings*, 9(5), 115.
- Kozlovska, M., Petkanic, S., Vranay, F., & Vranay, D. (2023). Enhancing Energy Efficiency and Building Performance through BEMS-BIM Integration. *Energies*, 16(17), 6327.
- Kreuger, L., & Neuman, W. L. (2006). Social work research methods: qualitative and quantitative approaches: with Research Navigator. (No Title).
- Kukah, A. S. K., Owusu-Manu, D.-G., Badu, E., Edwards, D. J., Asamoah, E., Anafo, A., Kuutiero, D., & Kukah, R. M. K. (2023). Evaluating the factors that influence public sector involvement in Ghanaian public-private partnership (PPP) power projects. *Journal of Facilities Management*, 45(2), 1-19.
- Kwofie, T. E., Amos-Abanyie, S., & Botchway, E. (2016). Critical professional competencies of architects in the Ghanaian construction industry.
- Lam, T., Mahdjoubi, L., & Mason, J. (2015). A web-based decision support system (DSS) to assist small and medium-sized enterprises (SMEs) to broker risks and rewards for BIM adoption. *Building Information Modelling (BIM) in Design, Construction and Operations*, 149, 463-475.
- Lamptey, T., Owusu-Manu, D.-G., Acheampong, A., Adesi, M., & Ghansah, F. A. (2021). A framework for the adoption of green business models in the Ghanaian construction industry. *Smart and Sustainable Built Environment*, 10(3), 536-553.
- Langston, C., & Zhang, W. (2021). DfMA: Towards an integrated strategy for a more productive and sustainable construction industry in Australia. *Sustainability*, 13(16), 9219.
- Latiffi, A. A., Brahim, J., & Fathi, M. (2017). Building information modelling (BIM) after ten years: Malaysian construction players' perception of BIM. IOP Conference Series: Earth and Environmental Science,

- Latiffi, A. A., Brahim, J., Mohd, S., & Fathi, M. S. (2015). Building information modeling (BIM): exploring level of development (LOD) in construction projects. *Applied Mechanics and Materials*, 773, 933-937.
- Lee, G., & Borrmann, A. (2020). BIM policy and management. In (Vol. 38, pp. 413-419): Taylor & Francis.
- Leech, N. L., & Onwuegbuzie, A. J. (2009). A typology of mixed methods research designs. *Quality & quantity*, 43, 265-275.
- Li, Zhen, Y., Wu, H., Chen, Z., Xiao, B., & Tam, V. W. (2023). The application of BIM in the AECO industry. *Journal of Civil Engineering and Management*, 29(3), 202–222.
- Li, J., Kassem, M., Ciribini, A., & Bolpagni, M. (2019). A proposed approach integrating DLT, BIM, IOT and smart contracts: Demonstration using a simulated installation task. International Conference on Smart Infrastructure and Construction 2019 (ICSIC) Driving data-informed decision-making,
- Li, P., Zheng, S., Si, H., & Xu, K. (2019). Critical Challenges for BIM Adoption in Small and Medium-Sized Enterprises: Evidence from China. *Advances in Civil Engineering*, 2019(1), 9482350.
- Liao, L., & Teo, E. A. L. (2017). Critical success factors for enhancing the building information modelling implementation in building projects in Singapore. *Journal of Civil Engineering and Management*, 23(8), 1029-1044.
- Liao, L., Teo, E. A. L., & Chang, R. (2019). Reducing critical hindrances to building information modeling implementation: the case of the Singapore construction industry. *Applied Sciences*, 9(18), 3833.
- Liao, X., Lee, C. Y., & Chong, H.-Y. (2019). Contractual practices between the consultant and employer in Chinese BIM-enabled construction projects. *Engineering, construction and architectural management*, 27(1), 227-244.
- Lin, J. J., & Golparvar-Fard, M. (2020). Construction progress monitoring using cyber-physical systems. *Cyber-physical systems in the built environment*, 63-87.
- Liu, D., Lu, W., & Niu, Y. (2018). Extended technology-acceptance model to make smart construction systems successful. *Journal of construction engineering and management*, 144(6), 04018035.
- Liu, Y., Van Nederveen, S., & Hertogh, M. (2017). Understanding effects of BIM on collaborative design and construction: An empirical study in China. *International journal of project management*, 35(4), 686-698.
- Liu, Z., Lu, Y., Nath, T., Wang, Q., Tiong, R. L. K., & Peh, L. L. C. (2022). Critical success factors for BIM adoption during construction phase: a Singapore case study. *Engineering, construction and architectural management*, 29(9), 3267-3287.
- Liu, Z., Lu, Y., & Peh, L. C. (2019). A review and scientometric analysis of global building information modeling (BIM) research in the architecture, engineering and construction (AEC) industry. *Buildings*, 9(10), 210-210.
- Liu, Z., Wang, Y., Osmani, M., & Demian, P. (2020). Leveraging Micro-Level Building Information Modeling for Managing Sustainable Design: United Kingdom Experience. *Advances in Civil Engineering*, 2020(1), 3641950.
- Loh, M. Y. (2014). Challanges of building information modelling (BIM) in project implementation.

- López, F. J., Lerones, P. M., Llamas, J., Gómez-García-Bermejo, J., & Zalama, E. (2018). A review of heritage building information modeling (H-BIM). *Multimodal Technologies and Interaction*, 2(2), 21.
- Lu, D. (2023). Architecture in the Age of Playfulness: Mapping a Framework for Global Historiography. In *The Routledge Companion to Contemporary Architectural History* (pp. 1-80). Routledge.
- Ma, X., Chan, A. P., Li, Y., Zhang, B., & Xiong, F. (2020). Critical strategies for enhancing BIM implementation in AEC projects: perspectives from Chinese practitioners. *Journal of construction engineering and management*, 146(2), 05019019.
- Ma, X., Darko, A., Chan, A. P., Wang, R., & Zhang, B. (2022). An empirical analysis of barriers to building information modelling (BIM) implementation in construction projects: evidence from the Chinese context. *International Journal of Construction Management*, 22(16), 3119-3127.
- Mahamadu, A.-M., Navendren, D., Manu, P., Joseph, R., & Dziekonski, K. (2017). Addressing challenges to building information modelling implementation in UK: Designers' perspectives. *Journal of Construction Project Management and Innovation*, 7(Supplement 1), 1908-1932.
- Mannino, A., Dejacó, M. C., & Re Cecconi, F. (2021). Building information modelling and internet of things integration for facility management—Literature review and future needs. *Applied Sciences*, 11(7), 3062.
- Manzoor, B., Othman, I., Gardezi, S. S. S., Altan, H., & Abdalla, S. B. (2021). BIM-based research framework for sustainable building projects: a strategy for mitigating BIM implementation barriers. *Applied Sciences*, 11(12), 5397-5397.
- Maqbool, R., Saiba, M. R., & Ashfaq, S. (2023). Emerging industry 4.0 and Internet of Things (IoT) technologies in the Ghanaian construction industry: sustainability, implementation challenges, and benefits. *Environmental Science and Pollution Research*, 30(13), 37076-37091.
- McDermot, E., Agdas, D., Rodríguez Díaz, C. R., Rose, T., & Forcael, E. (2022). Improving performance of infrastructure projects in developing countries: An Ecuadorian case study. *International Journal of Construction Management*, 22(13), 2469-2483.
- McLean, N. (2022). Research Context and Methodology. In *Protest Movements as Media Vehicles of the Brazilian New Right: A Study of Populist Discourses* (pp. 35-85). Springer. https://doi.org/https://doi.org/10.1007/978-981-19-4379-9_2
- Mellado, F., & Lou, E. C. (2020). Building information modelling, lean and sustainability: An integration framework to promote performance improvements in the construction industry. *Sustainable cities and society*, 61, 102355.
- Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.
- Meyer, J. W., & Rowan, B. (1977). Institutionalized organizations: Formal structure as myth and ceremony. *American Journal of sociology*, 83(2), 340-363.
- Mitera-Kiełbasa, E., & Zima, K. (2024). BIM policy trends in Europe: insights from a multi-stage analysis. *Applied Sciences*, 14(11), 4363.

- Momeni Rad, F., Sydora, C., & El-Basyouny, K. (2024). Leveraging generative design and point cloud data to improve conformance to passing lane layout. *Sensors*, 24(2), 318.
- Moore, D. R., & Dainty, A. R. J. (1999). Integrated project teams' performance in managing unexpected change events. *Team Performance Management: an international journal*.
- Moreno, C., Olbina, S., & Issa, R. (2014). Use of building information modeling for the design and construction of educational facilities. In *Computing in Civil and Building Engineering (2014)* (pp. 447-454).
- Morgan, B. (2017). *Organizing for technology in practice: implementing Building Information Modeling in a design firm* UCL (University College London)].
- Motalebi, M., Rashidi, A., & Nasiri, M. M. (2022). Optimization and BIM-based lifecycle assessment integration for energy efficiency retrofit of buildings. *Journal of Building Engineering*, 49, 104022.
- Mustapa, S. A. H. S., & Jamaluddin, N. A. (2022). Awareness Level and Challenges of Building Information Modelling (BIM) Implementation among Quantity Surveying Profession. *International Journal of Academic Reserach in Economics and Management Sciences*, 11(3).
- Na, S., Heo, S., Han, S., Shin, Y., & Roh, Y. (2022). Acceptance model of artificial intelligence (AI)-based technologies in construction firms: Applying the Technology Acceptance Model (TAM) in combination with the Technology–Organisation–Environment (TOE) framework. *Buildings*, 12(2), 90.
- Nardelli, E. (2019). BIM training in Brazil Preparing professionals for BIM adoption by public administration.
- Neely, A., Schooling, J., Boulton, C., & Lamb, K. (2019). Developing the capabilities for a digital built Britain. *Centre for Digital Built Britain*.
- Nguyen, Nguyen, T.-Q., Jin, R., Jeon, C.-H., & Shim, C.-S. (2022). BIM-based mixed-reality application for bridge inspection and maintenance. *Construction innovation*, 22(3), 487-503.
- Nguyen, T. A., Do, S. T., Pham, T.-A., Nguyen, D. H., & Tamura, H. (2022). Integration of H-BIM, Virtual Reality, and Augmented Reality in Digital Twin Era-A Case Study in Cultural Heritage. ICSCEA 2021: Proceedings of the Second International Conference on Sustainable Civil Engineering and Architecture,
- NIBS. (2021). *National BIM Standard – United States Version 4.0. National Institute of Building Sciences*. Retrieved 05/07/2024 from <https://www.nationalbimstandard.org>
- Noor, S., Junaidi, S. R., & Ramly, M. K. A. (2018). Adoption of building information modelling (bim): factors contribution and benefits. *Journal of Information System and Technology Management*, 3(10), 47-63.
- Norouzian, R. (2020). Sample size planning in quantitative L2 research: A pragmatic approach. *Studies in Second Language Acquisition*, 42(4), 849-870.
- Novieto, D. T., & Kportufe, G. S. (2022). Work-family conflict and project performance of construction professionals in a developing country: testing the mediating–moderating effect of project management self-efficacy.

- Engineering, construction and architectural management*, 29(9), 3331-3344.
- Ntim, E. O., & Botchway, T. P. (2023). Ghana Beyond Aid: A Bargaining Chip for Draconian Economic Policies in Ghana. *The African Review*, 1(2), 1-33.
- Ofori-Kuragu, J. K. (2020). Construction industry developments in Ghana. In *Improving the Performance of Construction Industries for Developing Countries*. <https://doi.org/10.1201/9780429322471-7>
- Ofori-Kuragu, J. K., Owusu-Manu, D. G., & Ayarkwa, J. (2016). The case for a construction industry council in Ghana. *Journal of Construction in Developing Countries*, 21(2). <https://doi.org/10.21315/jcdc2016.21.2.7>
- Ofori, D., & Fuseini, O. I. (2019). Electronic government procurement adoption in Ghana: Critical success factors. *Methodology*, 2020.
- Ofori, G. (2012). Developing the Construction Industry in Ghana: the case for a central agency. *A concept paper prepared for improving the construction industry in Ghana*. National University of Singapore, 13(1), 3-18.
- Ofori, G. (2018). Sustainable industrial development in the construction sector for urban youth employment creation. Ghana Academy of Arts and Sciences Conference on Sustainable African Cities, Ghana.
- Olanrewaju, O. I., Babarinde, S. A., Chileshe, N., & Sandanayake, M. (2021). Drivers for implementation of building information modeling (BIM) within the Nigerian construction industry. *Journal of Financial Management of property and Construction*, 26(3), 366-386.
- Olanrewaju, O. I., Kineber, A. F., Chileshe, N., & Edwards, D. J. (2022). Modelling the relationship between Building Information Modelling (BIM) implementation barriers, usage and awareness on building project lifecycle. *Building and Environment*, 207(3), 108556.
- Olatunji, O. A., Lee, J. J. S., Chong, H.-Y., & Akanmu, A. A. (2021). Building information modelling (BIM) penetration in quantity surveying (QS) practice. *Built Environment Project and Asset Management*, 11(5), 888-902.
- Olawumi, T. O., Chan, D. W., & Wong, J. K. (2017). Evolution in the intellectual structure of BIM research: A bibliometric analysis. *Journal of Civil Engineering and Management*, 23(8), 1060-1081.
- Olugboyega, O. (2024). Differential relationships in the BIM implementation process in a developing country: the role of essential BIM implementation strategies. *Engineering, construction and architectural management*, 31(8), 3283-3307.
- Olugboyega, O., Ojo, O. S., & Olanipekun, A. E. (2024). Development of BIM learning model for construction sites operatives. *Frontiers in Built Environment*, 10, 1452764.
- Olugboyega, O., Oseghale, G. E., & Aigbavboa, C. (2023). Multiple holistic case study of project-level building information modelling (BIM) adoption in Nigeria. *Construction innovation*, 23(3), 567-586.
- Olugboyega, O., & Windapo, A. (2019). A comprehensive BIM implementation model for developing countries: comprehensive BIM implementation model. *Journal of Construction Project Management and Innovation*, 9(2), 83-104.

- Olugboyega, O., & Windapo, A. (2022). Investigating the strategic planning of BIM adoption on construction projects in a developing country. *Journal of Construction in Developing Countries*, 27(2), 183-204.
- Omar, H., & Dulaimi, M. (2023). Solutions for effective diffusion of BIM for BIM late adopters: Case study of UAE AEC industry. *International Journal of Construction Management*, 23(9), 1484-1493.
- Omer, M. M., Mohd-Ezazee, N., Lee, Y. S., Rajabi, M. S., & Rahman, R. A. (2022). Constructive and destructive leadership behaviors, skills, styles and traits in BIM-based construction projects. *Buildings*, 12(12), 2068.
- Opoku, A., & Ibrahim-Adam, R. (2018). Early contractor involvement in government construction projects in Ghana. In: *(Proceedings) ARCOM Thirty-Fourth Annual Conference 2018*. (pp. pp. 199-208). Association of Researchers in Construction Management (ARCOM): Belfast, Northern Ireland. (2018). <http://www.arcom.ac.uk/conf-archive-indexed.php>
- Oraee, M., Hosseini, M. R., Edwards, D. J., Li, H., Papadonikolaki, E., & Cao, D. (2019). Collaboration barriers in BIM-based construction networks: A conceptual model. *International journal of project management*, 37(6), 839-854.
- Osabutey, E. L., & Croucher, R. (2018). Intermediate institutions and technology transfer in developing countries: The case of the construction industry in Ghana. *Technological Forecasting and Social Change*, 128, 154-163.
- Osei-Kyei, R., & Chan, A. P. (2017). Implementing public-private partnership (PPP) policy for public construction projects in Ghana: critical success factors and policy implications. *International Journal of Construction Management*, 17(2), 113-123.
- Osei-Tutu, S., Ayarkwa, J., Osei-Asibey, D., Nani, G., & Afful, A. E. (2023). Barriers impeding circular economy (CE) uptake in the construction industry. *Smart and Sustainable Built Environment*, 12(4), 892-918.
- Oteng, D., Ansah, M. K., Kissi, E., & Eshun, B. T. B. (2018). Barriers to the Adoption of Building Information Modelling in Developing Countries: The Case of Ghana. *1st International Conference on Construction Futures*(March 2020).
- Oti-Sarpong, K., Leiringer, R., & Zhang, S. (2020). A critical examination of BIM policy mandates: Implications and responses. Construction Research Congress 2020,
- Owoo, N. S., & Lambon-Quayefio, M. P. (2018). *The role of the construction sector in Ghana* (Vol. 2018). UNU-WIDER. <https://doi.org/10.35188/UNU-WIDER/2018/561-9>
- Owusu-Ansah, A., Soyeh, K. W., & Asabere, P. K. (2019). Developer constraints on housing supply in urban Ghana. *International Journal of Housing Markets and Analysis*.
- Owusu, E. K., Chan, A. P., Chen, L., & Amoah, P. (2022). Digitization, Digitalization, and Digital Transformation (3Ds): Explicating the Disparities and Applications of the 3Ds in the Construction Industry. Construction Research Congress 2022,
- Ozcan-Deniz, G., Ozorhon, B., & Kaya, O. C. (2024). Building Information Modeling (BIM) integration in developing countries: An in-depth

- examination of adoption factors from public clients' perspectives. *International Journal of Architectural Computing*, 14780771241270196.
- Pan, X., Khan, A. M., Eldin, S. M., Aslam, F., Rehman, S. K. U., & Jameel, M. (2023). BIM adoption in sustainability, energy modelling and implementing using ISO 19650: A review. *Ain Shams Engineering Journal*, 102252.
- Paneru, S., Ghimire, P., Kandel, A., Thapa, S., Koirala, N., & Karki, M. (2023). An Exploratory Investigation of Implementation of Building Information Modeling in Nepalese Architecture–Engineering–Construction Industry. *Buildings*, 13(2), 552-552.
- Papadonikolaki, E. (2018). Loosely coupled systems of innovation: Aligning BIM adoption with implementation in Dutch construction. *Journal of Management in Engineering*, 34(6), 05018009.
- Papadonikolaki, E., van Oel, C., & Kagioglou, M. (2019). Organising and Managing boundaries: A structural view of collaboration with Building Information Modelling (BIM). *International journal of project management*, 37(3), 378-394.
- Park, E., Kwon, S. J., & Han, J. (2019). Antecedents of the adoption of building information modeling technology in Korea. *Engineering, construction and architectural management*, 26(8), 1735-1749.
- Park, H., Park, J. S., Lee, H. R., & Kim, S. (2018). Public acceptance of a health information exchange in Korea. *Healthcare Informatics Research*, 24(4), 359-370.
- Patel, T., Bapat, H., Patel, D., & van der Walt, J. D. (2021). Identification of critical success factors (CSFs) of BIM software selection: A combined approach of FCM and Fuzzy DEMATEL. *Buildings*, 11(7), 311-311.
- Peng, P., Ao, Y., Li, M., Wang, Y., Wang, T., & Bahmani, H. (2022). Building Information Modeling Learning Behavior of AEC Undergraduate Students in China. *Behavioral Sciences*, 12(8), 269-269.
- Phung, Q., & Tong, N. (2021). Developing an organizational readiness framework for BIM implementation in large design companies. *International Journal of Sustainable Construction Engineering and Technology*, 12(3), 57-67.
- Pinti, L., Codinhoto, R., & Bonelli, S. (2022). A review of building information modelling (BIM) for facility management (FM): Implementation in public organisations. *Applied Sciences*, 12(3), 1540.
- Polkinghorne, M., & Taylor, J. (2022). Recursive abstraction method for analysing qualitative data.
- Prabhakaran, A., Mahamadu, A.-M., Mahdjoubi, L., Andric, J., Manu, P., & Mzyece, D. (2021). An investigation into macro BIM maturity and its impacts: a comparison of Qatar and the United Kingdom. *Architectural Engineering and Design Management*, 17(5-6), 496-515.
- Quinlan, C., Babin, B., Carr, J., & Griffin, M. (2019). *Business research methods*. South Western Cengage.
- Radzi, A. R., Bokhari, H. R., Rahman, R. A., & Ayer, S. K. (2019). Key Attributes of Change Agents for Successful Technology Adoptions in Construction Companies: A Thematic Analysis. *Computing in Civil Engineering 2019: Data, Sensing, and Analytics - Selected Papers from the ASCE International Conference on Computing in Civil Engineering 2019*,

- Rahman, R. A., & Ayer, S. K. (2017). Prevalent issues in BIM-based construction projects. Proceedings of joint conference on computing in construction,
- Raja Mohd Noor, R. N. H., Che Ibrahim, C. K. I., & Belayutham, S. (2021). Making sense of multi-actor social collaboration in building information modelling level 2 projects: A case in Malaysia. *Construction Economics and Building*, 21(4), 89-114.
- Rajendran, P., Seow, T. W., & Goh, K. C. (2014). Building information modeling (BIM) tools in design stage to assist in time for construction project success. *Int J Concept Manag Soc Sci*, 2(3), 52-71.
- Ramakrishna, P. (2023). A Multi-Level Perspective: Construction and Demolition Waste Management System: Case Study: Bengaluru. In.
- Reddy, K. P. (2011). *BIM for building owners and developers: making a business case for using BIM on projects*. John Wiley & Sons.
- Rogers, E. M. (1995). Diffusion of innovations—5th edition Free Press. New York.
- Rogers, E. M. (2010). *Diffusion of innovations*. Simon and Schuster.
- Rogers, E. M., Singhal, A., & Quinlan, M. M. (2019). Diffusion of innovations 1. *An integrated approach to communication theory and research*, 415-434.
- Rwelamila, P. D., Fewings, P., & Henjewe, C. (2015). Addressing the missing link in PPP projects: What constitutes the public? *Journal of Management in Engineering*, 31(5), 04014085-04014085.
- Sadeh, H., Mirarchi, C., & Pavan, A. (2023). Technological transformation of the construction sector: A conceptual approach. *International Journal of Construction Management*, 23(10), 1704-1714.
- Saka, A. B., Chan, D. W., & Mahamadu, A.-M. (2022). Rethinking the digital divide of BIM adoption in the AEC industry. *Journal of Management in Engineering*, 38(2), 04021092.
- Saka, A. B., & Chan, D. W. M. (2020). Profound barriers to building information modelling (BIM) adoption in construction small and medium-sized enterprises (SMEs): An interpretive structural modelling approach. *Construction innovation*, 20(2). <https://doi.org/10.1108/CI-09-2019-0087>
- Samimpay, R., & Saghatforoush, E. (2020). Benefits of Implementing Building Information Modeling (BIM) in Infrastructure Projects. *Journal of Engineering, Project, and Production Management*, 1(2), 123.
- Sampaio, A. Z., Gomes, A. M., & Farinha, T. (2021). BIM methodology applied in structural design: Analysis of interoperability in ArchiCAD/ETABS process. *Journal of Software Engineering and Applications*, 14(6), 189-206.
- Sanchez, B., Rausch, C., Haas, C., & Hartmann, T. (2021). A framework for BIM-based disassembly models to support reuse of building components. *Resources, Conservation and Recycling*, 175, 105825.
- Sanhudo, L., Poças Martins, J., Ramos, N. M., Almeida, R. M., Rocha, A., Pinto, D., Barreira, E., & Simões, M. L. (2021). BIM framework for the specification of information requirements in energy-related projects. *Engineering, construction and architectural management*, 28(10), 3123-3143.
- Saunders, M., Lewis, P., & Thornhill, A. (2012). Research methods for business students (6. utg.). Harlow: Pearson.

- Scott, W. R. (2005). Institutional theory: Contributing to a theoretical research program. *Great minds in management: The process of theory development*, 37(2), 460-484.
- Scott, W. R. (2017). Institutional theory: Onward and upward. *The Sage handbook of organizational institutionalism*, 853-869.
- Seale, C. (2017). Researching society and culture. *Researching Society and Culture*, 1-664.
- Semyachkov, K. (2019). Digital economy in developing countries: problems and prospects. 1st International Scientific Conference" Modern Management Trends and the Digital Economy: from Regional Development to Global Economic Growth"(MTDE 2019),
- Shafiq, M. T. (2021). Client-driven level 2 BIM implementation: a case study from the UAE. *The Open Construction & Building Technology Journal*, 15(1).
- Shen, L., Edirisinghe, R., & Yang, M. (2016). An investigation of BIM readiness of owners and facility managers in Singapore: Institutional case study. CIB World Building Congress,
- Shirowzhan, S., Sepasgozar, S. M., Edwards, D. J., Li, H., & Wang, C. (2020). BIM compatibility and its differentiation with interoperability challenges as an innovation factor. *Automation in construction*, 112, 103086.
- Shojaei, R. S., Oti-Sarpong, K., & Burgess, G. (2023). Enablers for the adoption and use of BIM in main contractor companies in the UK. *Engineering, construction and architectural management*, 30(4), 1726-1745.
- Sidani, A., Duarte, J., Baptista, J. S., Vaz, M., Martins, J. P., & Soeiro, A. (2021). BIM-based sensors technologies implemented in the construction site: protocol for a systematic review:(Protocol). *International Journal of Occupational and Environmental Safety*, 5(1), 25-31.
- Siddiqui, F. H., Abdekhodae, A., & Thaheem, M. J. (2022). Taxonomy of Digital Skills Needed in the Construction Industry: A Literature Review. Proceedings of the 45th AUBEA Conference, Sydney, Australia,
- Siebelink, S., Voordijk, H., Endedijk, M., & Adriaanse, A. (2021). Understanding barriers to BIM implementation: Their impact across organizational levels in relation to BIM maturity. *Frontiers of Engineering Management*, 8, 236-257.
- Sierra, F., & Rodboonpha, C. (2023). Building Information Modelling Implementation Models in Thailand: Drivers, Benefits, Barriers and Lessons Learned. *Journal of Construction in Developing Countries*, 28(2), 37-55.
- Sileyew, K. J. (2019). Research design and methodology. In *Cyberspace*. IntechOpen.
- Silverio, A. K., Suresh, S., Heesom, D., & Suresh, R. (2021). BIM Education in the Dominican Republic: A Framework to Guide the Implementation of BIM Into University Curricula. In *Handbook of Research on Driving Transformational Change in the Digital Built Environment* (pp. 327-359). IGI Global.
- Silverio, A. K., Suresh, S., Renukappa, S., & Heesom, D. (2023). Status of BIM implementation in the Dominican Republic construction industry—An empirical study. *Journal of Engineering, Design and Technology*, 21(2), 417-441.

- Silverman, D. (2017). How was it for you? The Interview Society and the irresistible rise of the (poorly analyzed) interview. *Qualitative research*, 17(2), 144-158.
- Smith, D. K., & Tardif, M. (2009). *Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers*. John Wiley & Sons.
- Somiah, M. K., Aigbavboa, C. O., & Thwala, W. D. (2020). Success strategies for competitive advantage in the Ghanaian construction industry: a Delphi study. *The Construction Industry in the Fourth Industrial Revolution: Proceedings of 11th Construction Industry Development Board (CIDB) Postgraduate Research Conference 11*,
- Steinhardt, D. A., & Manley, K. (2016). Exploring the beliefs of Australian prefabricated house builders. *Construction Economics and Building*, 16(2), 27-41.
- Succar, B. (2010). Building information modelling maturity matrix. In *Handbook of research on building information modeling and construction informatics: Concepts and technologies* (pp. 65-103). IGI Global.
- Succar, B., & Kassem, M. (2015). Macro-BIM adoption: Conceptual structures. *Automation in Construction*, 57, 64-79.
- Succar, B., & Kassem, M. (2016). Building information modelling: Point of adoption. *CIB World Conference Proceedings*,
- Succar, B., Sher, W., & Williams, A. (2012). Measuring BIM performance: Five metrics. *Architectural Engineering and Design Management*, 8(2), 120-142.
- Succar, B., Sher, W., & Williams, A. (2013). An integrated approach to BIM competency assessment, acquisition and application. *Automation in Construction*, 35, 174-189.
- Sun, C., Jiang, S., Skibniewski, M. J., Man, Q., & Shen, L. (2017). A literature review of the factors limiting the application of BIM in the construction industry. *Technological and Economic Development of Economy*, 23(5), 764-779.
- Tahir, M. M., Haron, N. A., Alias, A. H., Al-Jumaa, A. T., Muhammad, I. B., & Harun, A. N. (2018). Applications of building information model (BIM) in Malaysian construction industry. *IOP Conference Series: Materials Science and Engineering*,
- Takyyi-Annan, G. E., & Zhang, H. (2023a). Assessing the impact of overcoming BIM implementation barriers on BIM usage frequency and circular economy in the project lifecycle using Partial least Squares structural Equation modelling (PLS-SEM) analysis. *Energy and Buildings*, 295(2), 113329.
- Takyyi-Annan, G. E., & Zhang, H. (2023b). A multivariate analysis of the variables impacting the level of BIM expertise of professionals in the architecture, engineering and construction (AEC) industries of the developing world using nonparametric tests. *Buildings*, 13(7), 1606.
- Tan, S., & Gumusburun Ayalp, G. (2022). Root factors limiting BIM implementation in developing countries: sampling the Turkish AEC industry. *Open House International*, 47(4), 732-762.

- Tee, Y. Y., & Kamal, E. M. (2021). The revolution of quantity surveying profession in building information modelling (BIM) era: The Malaysian perspective. *International Journal of Sustainable Construction Engineering and Technology*, 12(1), 185-195.
- Teizer, J., Wolf, M., Golovina, O., Perschewski, M., Propach, M., Neges, M., & König, M. (2017). Internet of Things (IoT) for integrating environmental and localization data in Building Information Modeling (BIM). ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction,
- Teo, M. M., & Loosemore, M. (2017). Understanding community protest from a project management perspective: A relationship-based approach. *International journal of project management*, 35(8), 1444-1458.
- Tezel, A., & Aziz, Z. (2017). Benefits of visual management in construction: cases from the transportation sector in England. *Construction innovation*, 17(2), 125-157.
- Tian, L., Wright, A., Painter, B., & Pazhoohesh, M. (2023). Factors influencing BIM use in green building construction project management in the UK and China. *Building Research & Information*, 1-18.
- Toklu, S., & Mayuk, S. G. (2020). The implementation of building information modelling (BIM) in Turkey. ICONARCH International Congress of Architecture and Planning,
- Towey, D. (2013). *Cost management of construction projects*. John Wiley & Sons.
- Toyin, J. O., & Mewomo, M. C. (2023). An investigation of barriers to the application of building information modelling in Nigeria. *Journal of Engineering, Design and Technology*, 21(2), 442-468.
- Troiani, E., Mahamadu, A.-M., Manu, P., Kissi, E., Aigbavboa, C., & Oti, A. (2020). Macro-maturity factors and their influence on micro-level BIM implementation within design firms in Italy. *Architectural Engineering and Design Management*, 16(3), 209-226.
- Ullah, K., Lill, I., & Witt, E. (2019). An overview of BIM adoption in the construction industry: Benefits and barriers. 10th Nordic conference on construction economics and organization,
- Ullah, K., Witt, E., & Lill, I. (2022). The BIM-based building permit process: Factors affecting adoption. *Buildings*, 12(1), 45.
- Underwood, J., Isikdag, U., Goulding, J., & Kuruoglu, M. (2010). A comparative analysis of the strategic role of ICT in the UK and Turkish construction industries. W078-Special Track 18th CIB World Building Congress May 2010 Salford, United Kingdom,
- Vanderstoep, S. W., & Johnson, D. D. (2008). *Research methods for everyday life: Blending qualitative and quantitative approaches*. John Wiley & Sons.
- Varadarajan, R. (2020). Customer information resources advantage, marketing strategy and business performance: A market resources based view. *Industrial Marketing Management*, 89, 89-97.
- Vigneshwar, R., Shanmugapriya, S., & Sindhu Vaardini, U. (2022). Analyzing the driving factors of BIM adoption based on the perception of the practitioners in Indian construction projects. *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, 46(3), 2637-2648.

- Vitente, L. S., Ong, A. K. S., & German, J. D. (2024). Assessment of Adoption and Acceptance of Building Information Modeling for Building Construction among Industries in Qatar. *Buildings*, 14(5), 1433.
- Wang, L., Huang, M., Zhang, X., Jin, R., & Yang, T. (2020). Review of BIM adoption in the higher education of AEC disciplines. *Journal of Civil Engineering Education*, 146(3), 06020001.
- Watts, G., McDermott, P., & Kolo, S. (2023). Framing the barriers to construction industry transformation. *Built Environment Project and Asset Management*, 13(1), 185-199.
- West, J., & Liu, J. (2021). Building Information Modelling Usage in Federal Hydropower Design and Construction Management. IOP Conference Series: Materials Science and Engineering,
- Weygant, R. S. (2011). *BIM content development: standards, strategies, and best practices*. John Wiley & Sons.
- Whitlock, K., Abanda, F., Manjia, M., Pettang, C., & Nkeng, G. (2021). Germany's Governmental BIM Initiative—The BIM4INFRA2020 Project Implementing the BIM Roadmap. *CivilEng*. In.
- Won, J., Lee, G., Dossick, C., & Messner, J. (2013). Where to focus for successful adoption of building information modeling within organization. *Journal of construction engineering and management*, 139(11), 04013014.
- Wong, A. K., Wong, F. K., & Nadeem, A. (2011). Government roles in implementing building information modelling systems: Comparison between Hong Kong and the United States. *Construction innovation*, 11(1), 61-76.
- Wong, J. H., Rashidi, A., & Arashpour, M. (2020). Evaluating the impact of building information modeling on the labor productivity of construction projects in Malaysia. *Buildings*, 10(4), 66.
- World Bank. (2024). *The World Bank in Middle Income Countries*. The World Bank Group. Retrieved 25/09/2024 from <https://www.worldbank.org/en/country/mic/overview>
- Wu, C., Xu, B., Mao, C., & Li, X. (2017). Overview of BIM maturity measurement tools. *Journal of Information Technology in Construction (ITcon)*, 22(3), 34-62.
- Wu, P., Jin, R., Xu, Y., Lin, F., Dong, Y., & Pan, Z. (2021). The analysis of barriers to BIM implementation for industrialized building construction: A China study. *Journal of Civil Engineering and Management*, 27(1), 1-13.
- Wu, W., & Issa, R. R. A. (2014). BIM education and recruiting: Survey-based comparative analysis of issues, perceptions, and collaboration opportunities. *Journal of Professional Issues in Engineering Education and Practice*, 140(2), 04013014-04013014.
- Xia, X., Wu, X., BalaMurugan, S., & Karuppiah, M. (2021). Effect of environmental and social responsibility in energy-efficient management models for smart cities infrastructure. *Sustainable Energy Technologies and Assessments*, 47, 101525.
- Xu, J., Lu, W., & Papadonikolaki, E. (2022). Human-organization-technology fit model for BIM adoption in construction project organizations: Impact factor analysis using SNA and comparative case study. *Journal of Management in Engineering*, 38(3), 04022004-04022004.

- Yan, H., & Demian, P. (2008). Benefits and barriers of building information modelling.
- Yeboah, K. O., Mensah, N. O., Tandoh, I., Roberts, N. J. T., & Duffour, K. A. (2023). Antecedents of marketing climate change adaption construction materials: Evidence from Ghana. *Economics, Management and Sustainability*, 8(2), 81-92.
- Yilmaz, G., Akcamete, A., & Demirors, O. (2019). A reference model for BIM capability assessments. *Automation in Construction*, 101, 245-263.
- Yilmaz, G., Akcamete, A., & Demirors, O. (2023). BIM-CAREM: Assessing the BIM capabilities of design, construction and facilities management processes in the construction industry. *Computers in Industry*, 147, 103861.
- Yu, W.-D., Chang, H.-K., & Wang, K.-C. (2023). Measuring the value and cost of BIM use—an empirical lesson learned from Taiwan's social housing projects. *Canadian Journal of Civil Engineering*, 50(12), 1047-1065.
- Yuan, H., Yang, Y., & Xue, X. (2019). Promoting owners' BIM adoption behaviors to achieve sustainable project management. *Sustainability*, 11(14), 3905.
- Yusuf, A. O., Opawole, A., Musa, N. A., Kadiri, D. S., & Ebunoluwa, E. I. (2024). Factors influencing the organisational capabilities of the public sector for implementation of building information modelling in construction projects. *International Journal of Building Pathology and Adaptation*, 42(5), 1058-1083.
- Zaid, S., Zaid, L. M., Esfandiari, M., & Abu Hasan, Z. F. (2022). Green roof maintenance for non-residential buildings in tropical climate: case study of Kuala Lumpur. *Environment, Development and Sustainability*, 1-26.
- Zaineldeen, S., Hongbo, L., Koffi, A., & Hassan, B. (2020). Technology acceptance model'concepts, contribution, limitation, and adoption in education. *Universal Journal of Educational Research*, 8(11), 5061-5071.
- Zakaria, Y. A., Agamba, M. A., & Musah, M. E. I. (2023). Multi-stakeholder involvement in urban market infrastructure renewals in the Aboabo and Central markets of the Tamale Metropolitan District in Ghana: An application of the stakeholder theory. *Regional Science Policy & Practice*, 15(6), 1240-1259.
- Zaker Hosein, M. R. (2019). BIM implementation in architectural practices: towards advanced collaborative approaches based on digital technologies.
- Zhang, H. M., Chong, H.-Y., Zeng, Y., & Zhang, W. (2023). The effective mediating role of stakeholder management in the relationship between BIM implementation and project performance. *Engineering, construction and architectural management*, 30(6), 2503-2522.
- Zhang, J., Cheng, J. C., Chen, W., & Chen, K. (2022). Digital twins for construction sites: Concepts, LoD definition, and applications. *Journal of Management in Engineering*, 38(2), 04021094.
- Zhang, R., Tang, Y., Wang, L., & Wang, Z. (2020). Factors influencing BIM adoption for construction enterprises in China. *Advances in Civil Engineering*, 2020, 1-15.
- Zhou, Y., Yang, Y., & Yang, J.-B. (2019). Barriers to BIM implementation strategies in China. *Engineering, construction and architectural management*, 26(3), 554-574.

Zhu, R., Becerik-Gerber, B., Lin, J., & Li, N. (2023). Behavioral, data-driven, agent-based evacuation simulation for building safety design using machine learning and discrete choice models. *Advanced Engineering Informatics*, 55, 101827.