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Review article

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Revisiting what factors promote BIM adoption more effectively through the TOE framework: A meta-analysis

Appendix A

A1 Including national BIM maturity assessment criteria in the meta-analysis

Component	Maturity level	Description
		The United States
Objectives, stages and milestones level	4	BIM goals and stages have been integrated into the National Standards document：National BIM Standard - United States (NIBS).
Champions and drivers level	4	The NIBS BIM Council is the national driver that coordinates all macro adoption activities.
Regulatory framework level	4	The National BIM Standard (NBIMS-US) has been integrated into all requirements, roles, processes and deliverables.
Noteworthy publications level	4	The noteworthy BIM publications (NBP), National BIM Standard - United States, are authoritative, interrelated and integrated throughout the project lifecycle stage and supply chain.
Learning and education level	3	BIM Learning Providers: Entities such as the Associated General Contractor of the United States (AGC) offer interdisciplinary and specialized accredited courses.
Measurements and benchmarks level	4	The National BIM Standard (NBIMS-US) has been integrated into project requirements, workflows and deliverables.
Standardised parts and deliverables level	4	The National BIM Standard (NBIMS-US) integrates standardized object libraries, service delivery model usage, and operational data requirements into procurement mechanisms, project workflows, and lifecycle facility operations.
Technology infrastructure level	3	The technical infrastructure is of sufficient quality and affordability to implement BIM within an organization and spread it across different market segments such as Revit, Navisworks, and others.
		The United Kingdom
Objectives, stages and milestones level	4	BIM objectives and stages have been integrated into the BS EN ISO 19650 national standard.
Champions and drivers level	4	BSI (British Standards Institution) this country driver coordinates all macro adoption activities.
Regulatory framework level	4	BS EN ISO 19650, the national BIM standard, is integrated into all requirements, roles, processes and deliverables.
Noteworthy publications level	5	BS EN ISO 19650, this Noteworthy BIM Publications (NBP) reflects international best practice.
Learning and education level	4	BIM learning bodies are integrated across higher education and professions (for example, the University of Cambridge has opened a Building Information Modelling School with teachers from education and industry).
Measurements and benchmarks level	5	The national BIM standard BS EN ISO 19650 has been integrated into project requirements, workflows and deliverables, translating international best practices.

Component	Maturity level	Description
Standardised parts and deliverables level	4	The Asset delivery phase (ISO 19650-2) in the ISO 19650 series of national BIM standards integrates standardized object libraries, service delivery model usage, and operational data requirements into procurement mechanisms, project workflows, and lifecycle facility operations.
Technology infrastructure level	4	Technology infrastructure is uniformly accessible and interoperable: The widely used Common Data Environment (CDE) platform enables data sharing and collaboration.
		Spain
Objectives, stages and milestones level	4	BIM objectives and phases have been integrated into the BIM implementation strategy national standard.
Champions and drivers level	3	the Ministerio de Fomento (Ministry of Development) created the "BIM Commission", a national driver that coordinates all macro adoption activities.
Regulatory framework level	4	The BIM implementation strategy, a national BIM standard, is integrated into all requirements, roles, processes and deliverables.
Noteworthy publications level	3	Noteworthy BIM Publications (NBP) is coordinated by a single entity, the Spanish Ministry of Development.
Learning and education level	3	BIM learning topics correspond to current urgent roles, and BIM learning providers offer interdisciplinary and professional accredited courses.
Measurements and benchmarks level	2	There are formal indicators in the BIM implementation strategy to measure project outcomes and assess the capabilities of individuals, organizations and teams in the market.
Standardised parts and deliverables level	4	ISO 16739 is an international standard that defines the IFC format characteristics for data sharing in BIM processes. Has been included in the public tender as a Spanish requirement.
Technology infrastructure level	2	The technical infrastructure is of sufficient quality and affordability and there are various outsourcing companies.
		Australia
Objectives, stages and milestones level	4	BIM goals and stages are integrated into the national standard: NATSPEC National BIM Guide.
Champions and drivers level	4	The Council of Australian Governments' (COAG) Transport Infrastructure Council, the national driver coordinating all macro adoption activities.
Regulatory framework level	4	The NATSPEC National BIM Guide is a national BIM standard integrated into all requirements, roles, processes and deliverables.
Noteworthy publications level	3	noteworthy BIM publications (NBP) is coordinated by a single entity: The Council of Australian Governments' (COAG) Transport Infrastructure Council.
Learning and education level	3	The BIM courses offered by different tertiary institutions in Australia vary widely in quality and content.
Measurements and benchmarks level	2	The Australasian BIM Benefits Reporting (ABBR), this formal indicator is used to measure project outcomes and assess the capabilities of individuals, organisations and teams in the market.
Standardised parts and deliverables level	4	BIMcontent.com and other platforms dedicated to hosting and sharing BIMcontent.
Technology infrastructure level	3	The technology infrastructure is high quality and affordable, enabling efficient exchange, storage, and management of complex federated models between decentralized project teams.
		Singapore

Component	Maturity level	Description
Objectives, stages and milestones level	4	BIM objectives and stages have been integrated into the national standard: Singapore BIM Guide Version 2.
Champions and drivers level	3	Building and Construction Authority (BCA), this unified organization that drives the implementation and dissemination of BIM throughout the market.
Regulatory framework level	4	The Singapore BIM Guide, a national BIM standard, is integrated into all requirements, roles, processes and deliverables.
Noteworthy publications level	4	Singapore BIM Guide, this noteworthy BIM publications (NBP) is authoritative, interrelated and integrated throughout the project lifecycle stage and supply chain.
Learning and education level	4	BIM learning bodies are integrated across higher education and professions, such as the National University of Singapore (NUS) and Nanyang Technological University (NTU), which have BIM-related courses.
Measurements and benchmarks level	4	The Singapore BIM Guide Version2 has been integrated into project requirements, workflows and deliverables.
Standardised parts and deliverables level	4	The Singapore BIM Guide Version2 integrates standardized object libraries, service delivery model usage and operational data requirements into procurement mechanisms, project workflows and lifecycle facility.
Technology infrastructure level	2	The technical infrastructure is of sufficient quality and capacity to implement BIM within an organization and to disseminate it across different market segments.
		South Korea
Objectives, stages and milestones level	4	BIM goals and stages have been integrated into the national standard: the Basic BIM Guidelines.
Champions and drivers level	4	Ministry of Land, Infrastructure and Transport, this national driver coordinates all macro adoption activities.
Regulatory framework level	4	Basic BIM Guidelines, a national BIM standard, is integrated into all requirements, roles, processes and deliverables
Noteworthy publications level	4	Basic BIM Guidelines, this noteworthy BIM publications (NBP) is authoritative, interrelated and integrated throughout the project lifecycle stage and supply chain.
Learning and education level	3	Many universities such as Seoul National University and Korea University of Science and Technology offer BIM courses, while professional training institutions also offer BIM certification courses.
Measurements and benchmarks level	2	There are formal indicators in the Basic BIM Guidelines for measuring project outcomes and assessing the capabilities of individuals, organizations and teams in the market.
Standardised parts and deliverables level	3	The standardized object library can be used: Civil Library: the "BIM library of civil facilities" in the construction enterprise information portal system; Building Library: "KBIMS Library" in KBIMS Performance Open Portal.
Technology infrastructure level	3	High quality and affordable technical infrastructure.The Basic BIM Guidelines lay the foundation for the National BIM Center.
		New Zealand
Objectives, stages and milestones level	4	BIM objectives and stages have been integrated into the national standard: New Zealand BIM Handbook.
Champions and drivers level	4	The BIMinNZ Steering Committee is the national driver that coordinates all macro adoption activities.
Regulatory framework level	4	The NZ BIM Handbook is a national BIM standard that is integrated into all

Component	Maturity level	Description
		requirements, roles, processes and deliverables.
Noteworthy publications level	4	The noteworthy BIM publications (NBP), the New Zealand BIM Handbook, is authoritative, interrelated and integrated throughout the project lifecycle stage and supply chain.
Learning and education level	4	The BIM learning body is integrated across higher education and professions, such as the University of Auckland and the University of Canterbury offering BIM related courses.
Measurements and benchmarks level	4	The New Zealand BIM Handbook has been integrated into project requirements, workflows and deliverables.
Standardised parts and deliverables level	3	A standardized Object library is available and used :open BIM Object standard.
Technology infrastructure level	3	The technical infrastructure is of high quality and affordable.
		China
Objectives, stages and milestones level	3	BIM goals, stages and milestones have been centrally managed and monitored in the national standard: Unified Standard for the Application of Building Information Models.
Champions and drivers level	4	The national and local ministries of Housing and Urban-Rural Development have unified macro-control and vigorously promoted the national smart construction pilot cities.
Regulatory framework level	2	The Chinese government has developed several BIM standards and guidelines that address the basic BIM rights and responsibilities of many stakeholders, but the development is uneven across provinces and cities.
Noteworthy publications level	3	noteworthy BIM publications (NBP) is coordinated by a single entity, the Ministry of Housing and Urban-Rural Development.
Learning and education level	2	Many universities such as Tsinghua University and Tongji University have opened BIM courses, and professional training institutions also offer a variety of BIM certification courses. But the theme does not correspond to the current needs.
Measurements and benchmarks level	2	The Uniform Standard for the Application of Building Information Models has formal indicators for measuring project results and assessing the capabilities of individuals, organizations and teams in the market.
Standardised parts and deliverables level	2	Object libraries are available, but follow different modeling and classification specifications, which vary widely across the country.
Technology infrastructure level	3	The technology infrastructure is high quality and affordable.
		Malaysia
Objectives, stages and milestones level	3	BIM goals, stages and milestones have been centrally managed and monitored in the Malaysian BIM Guide 5, but the process and techniques are not adequately reflected.
Champions and drivers level	4	The Construction Industry Development Board (CIDB) is the national driver that coordinates all macro adoption activities.
Regulatory framework level	2	IM guide 5 addresses the basic BIM rights and responsibilities of many stakeholders.
Noteworthy publications level	3	The Noteworthy BIM Publications (NBP) is coordinated by a single entity: the Construction Industry Development Board (CIDB).
Learning and education level	2	Technical University Malaysia (UTM) and International Islamic University Malaysia (IIUM) offer BIM courses. There is a shortage of competent and reliable BIM modelers among AEC professionals with technical knowledge of BIM software.

Component	Maturity level	Description
Measurements and benchmarks level	2	BIM guide 5 has formal metrics for measuring project outcomes and assessing the capabilities of individuals, organizations and teams in the market.
Standardised parts and deliverables level	3	A standardized object library is available and used :Malaysian BIM Guide 5 has the Exchange Information Requirement.
Technology infrastructure level	4	Establish a myBIM Center as a one-stop resource for reference, support, service and capacity building.
		India
Objectives, stages and milestones level	2	There are clearly defined macro BIM objectives, but no formal monitoring.
Champions and drivers level	3	IBIMA-India Building Information Modelling Association, a unified organization that drives the implementation and dissemination of BIM throughout the market.
Regulatory framework level	1	There is no formal regulatory framework for the BIM.
Noteworthy publications level	2	There are a large number of BIM publications, such as 2023 Proceedings of the 40th ISARC, Chennai, India, etc., which cover all aspects of knowledge content, but there is a certain degree of overlap and knowledge gap.
Learning and education level	1	Traditional education does not identify and does not include BIM learning topics.
Measurements and benchmarks level	1	There are no market-wide indicators applicable to measuring BIM proliferation, organizational capabilities, or project performance.
Standardised parts and deliverables level	2	Object libraries are available, but follow different modeling and classification specifications.
Technology infrastructure level	1	The technical infrastructure is inadequate.
		Ghana
Objectives, stages and milestones level	1	There is no market-scale BIM target.
Champions and drivers level	1	There is no clear pioneer.
Regulatory framework level	1	There is no formal regulatory framework for the BIM.
Noteworthy publications level	1	BIM publications and practices in Ghana are in their infancy and there are few authoritative BIM guidelines or standards in the market.
Learning and education level	1	Traditional education does not identify and does not include BIM learning topics.
Measurements and benchmarks level	1	BIM measurement and benchmarking have not yet resulted in widely accepted market-wide standards.
Standardised parts and deliverables level	1	There are libraries of market-specific objects.
Technology infrastructure level	1	The technical infrastructure is inadequate.
		Nigeria
Objectives, stages and milestones level	1	There is no market-scale BIM target.
Champions and drivers level	1	There is no clear pioneer.
Regulatory framework level	1	There is no formal regulatory framework for the BIM.
Noteworthy publications level	1	BIM practices and publications in Nigeria are still in their infancy and lack systematic guidance and standards.
Learning and education level	1	Traditional education does not identify and does not include BIM learning topics.
Measurements and benchmarks	1	BIM measurement and benchmarking have not yet resulted in widely

Component	Maturity level	Description
level		accepted market-wide standards.
Standardised parts and deliverables level	1	There are libraries of market-specific objects.
Technology infrastructure level	1	The technical infrastructure is inadequate.
		Peru
Objectives, stages and milestones level	1	There is no market-scale BIM target.
Champions and drivers level	3	The Peruvian Ministry of Economy and Finance (MEF) is a unified organization that promotes the implementation and dissemination of BIM throughout the market.
Regulatory framework level	1	There is no formal regulatory framework for the BIM.
Noteworthy publications level	2	There are a large number of BIM publications, such as GUIA NACIONAL BIM, which cover all aspects of knowledge content, but there is a certain degree of overlap and knowledge gaps.
Learning and education level	2	BIM learning subjects were identified and introduced into educational training programs. The Pontifical Catholic University of Peru has offered an optional BIM module in its civil engineering curriculum since 2014.
Measurements and benchmarks level	1	BIM measurement and benchmarking have not yet resulted in widely accepted market-wide standards.
Standardised parts and deliverables level	1	There are libraries of market-specific objects.
Technology infrastructure level	1	The technical infrastructure is inadequate.

Detailed definitions of the eight components of the BIM Maturity Model and research samples of the criteria for which stage of the BIM Maturity Model they belong to are from Succar and Kassem (2015).

A2 The factors that influence the BIM adoption included in various studies (N= 62)

Author(s)	TOE								TAM		BIM adoption
	Technical			Organizational			Environmental				
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	
Son et al. (2012)		√	√	√	√	√			√	√	√
Cao et al. (2014)				√			√	√			√
Xu et al. (2014)		√		√	√				√	√	√
Lee et al. (2015)	√				√	√			√	√	√
Ding et al. (2015)			√	√	√	√					√
Rogers et al. (2015)					√	√	√				√
Son et al. (2015)		√		√	√				√	√	√
Lee and Yu (2016)1	√				√		√	√	√	√	√
Lee and Yu (2016)2	√				√		√	√	√	√	√
Kim et al. (2016)	√	√	√						√	√	√
Cao et al. (2016)				√		√		√			√
Ahuja et al. (2016)	√	√	√	√	√	√					√
Hong et al.(2016)		√		√		√			√	√	√
Haliburton (2016)					√	√					√
Zheng et al. (2016)		√		√	√				√	√	√
Howard et al. (2017)						√					√
Wang and Song (2017)				√					√	√	√
Yuan (2017)		√			√	√					√
Acquah et al. (2018)									√	√	√
Zhang (2018)				√					√	√	√
Geng (2018)	√	√			√		√	√			√
Wang (2018)	√				√	√			√	√	√
Li (2018)		√							√	√	√
Liu (2019)	√	√	√		√	√	√	√	√	√	√
Ismail et al. (2019)	√								√		√
Lu et al. (2019)				√			√	√			√
Chen et al. (2019)1	√	√	√	√	√		√	√			√
Chen et al. (2019)2	√	√	√	√	√		√	√			√
Hong et al. (2019)	√	√			√	√					√
Gong et al. (2019)	√	√							√	√	√
Zhong (2019)					√	√					√
Hu (2019)					√					√	√
Zhou (2019)	√	√			√	√					√
Liu et al. (2019)		√		√							√
Zhang et al. (2019)				√	√	√					√
Qin et al. (2020)	√	√		√	√		√	√	√	√	√
Zhang et al. (2020)	√				√		√				√
Wang et al. (2020a)	√					√	√	√		√	√
Lee and Yu (2020)					√	√			√	√	√
Wang, et al. (2020b)				√	√				√	√	√
Okakpu et al. (2020)						√					√
Xu et al. (2020)	√	√								√	
Sanchís-Pedregosa et al. (2020)									√	√	√

Author(s)	TOE								TAM		BIM adoption
	Technical			Organizational			Environmental				
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	
Ma et al. (2020b)		√			√	√	√				√
Yuan et al. (2020)	√			√			√	√	√	√	√
Ma et al. (2020a)					√				√		√
Liao and Teo (2020)		√		√							√
Yang (2020)		√		√					√	√	√
Shehzad et al. (2020)	√	√			√		√	√			√
Ville-Manzares et al. (2020)				√	√	√					√
Baharuddin et al. (2021)					√				√	√	√
Wu et al. (2021)	√	√			√		√				√
Murguia et al. (2021)	√			√	√	√					√
Wang et al. (2021)	√	√	√						√		√
Cui et al. (2021)									√	√	√
Cao et al. (2022)				√	√	√					√
Saka et al. (2024)							√	√			√
Tavallaei et al. (2022)1				√							√
Tavallaei et al. (2022)2				√							√
Tavallaei et al. (2022)3				√							√
Vigneshwar et al. (2022)		√			√				√	√	√
Zhao et al. (2023)		√							√	√	√

Note： V1=Relative Advantage; V2=Compatibility; V3=Complexity; V4=Top Management Support; V5=Organizational Readiness; V6=Organizational Culture; V7=Coercive Pressures; V8=Mimetic Pressures; V9=Perceived Usefulness; V10=Perceived Ease of Use;

The article by Saka et al. (2024) was published online on 6 September 2022, but it was included in a journal issue that was published later on 2 January 2024. Consequently, it has been categorized under the year 2022 in our meta-analysis.

A3 Characteristics of studies included in the meta-analysis (N= 62)

Authors and Year of publication	Journal	N	Country	Organization type	Job level	Theories used or factors of influence involved
Son et al. (2012)	Automation in Construction	144	Korea	Construction	All employees	TAM DIT
Cao et al. (2014)	Journal of Construction engineering and management	92	China	All project stakeholders	Management	Institutional Theory(INT)
Xu et al. (2014)	Automation in Construction	98	China	All project stakeholders	All employees	TAM DIT
Lee et al. (2015)	Journal of management in engineering	114	Korea	All project stakeholders	Management	TAM
Ding et al. (2015)	Engineering, Construction and Architectural Management	181	China	Design	All employees	Inferential Behavior Theory
Rogers et al. (2015)	Engineering, Construction and Architectural Management	70	Malaysia	Engineering and Consulting Services	Management	Deductive Reasoning
Son et al. (2015)	Automation in Construction	162	Korea	Design	All employees	TAM
Lee and Yu (2016)1	ournal of Construction engineering and management	114	Korea	All project stakeholders	All employees	TAM
Lee and Yu (2016)2	ournal of Construction engineering and management	50	US	All project stakeholders	All employees	TAM
Kim et al. (2016)	KSCE Journal of Civil Engineering	303	Korea	All project stakeholders	All employees	TAM DIT
Cao et al. (2016)	Journal of Management in Engineering	81	China	All project stakeholders	All employees	INT DIT
Ahuja et al. (2016)	Architectural engineering and design management	184	India	All project stakeholders	All employees	TOE
Hong et al.(2016)	Proceedings of the international symposium on automation and robotics in Construction	40	Australia	All project stakeholders	Management	TAM
Haliburton. (2016)	Doctoral dissertation	95	US	All project stakeholders	All employees	Deductive Reasoning
Zheng et al. (2016)	Science and technology management research	566	China	All project stakeholders	All employees	TAM
Howard et al. (2017)	International Journal of Project Management	84	UK	All project stakeholders	General employees	Unified Theory of Acceptance and Use of Technology(UTAUT)
Wang and Song (2017)	Computers in Human Behavior	118	China	All project stakeholders	All employees	TAM
Yuan (2017)	Doctoral dissertation, Chongqing University	278	China	Design	Management	UTAUT
Acquah et al. (2018)	Journal of Information Technology in Construction	125	Ghana	Engineering and Consulting Services	All employees	TAM
Zhang (2018)	Journal of Civil Engineering and Management	437	China	All project stakeholders	All employees	TAM
Geng (2018)	Master's thesis, Chongqing University	306	China	Construction	Management	TOE

Authors and Year of publication	Journal	N	Country	Organization type	Job level	Theories used or factors of influence involved
Wang (2018)	Master's thesis, Zhengzhou University	117	China	Construction	All employees	TAM DIT
Li (2018)	Master's thesis, Shenzhen University	229	China	All project stakeholders	All employees	TAM TOE
Liu (2019)	Master's thesis, Zhejiang University	259	China	Construction	All employees	TAM
Ismail et al. (2019)	In IOP Conference Series: Earth and Environmental Science	202	Malaysia	All project stakeholders	General employees	TAM
Lu et al. (2019)	Sustainability	338	China	All project stakeholders	Management	TOE DIT
Chen et al. (2019)1	Engineering, Construction and architectural management	321	China	Engineering and Consulting Services	General employees	TOE
Chen et al. (2019)2	Engineering, Construction and architectural management	175	China	Construction	General employees	TOE
Hong et al. (2019)	Engineering, Construction and Architectural Management	80	Australia	Construction	All employees	DIT
Gong et al. (2019)	Sustainability	92	China	All project stakeholders	All employees	TAM
Zhong (2019)	Master's thesis, Chongqing University	180	China	Construction	All employees	UTAUT2
Hu (2019)	Master's thesis, Tianjin University of Technology	362	China	Construction	General employees	Theory of Planned Behavior(TPB)
Zhou (2019)	Master's thesis, Shenzhen University	374	China	Design	All employees	Input-Process-Output(IPO)
Liu et al. (2019)	Journal of Civil engineering	118	China	All project stakeholders	All employees	TOE
Zhang et al. (2019)	Sustainability	353	China	All project stakeholders	All employees	TPB
Qin et al. (2020)	Journal of Civil Engineering and Management	120	China	All project stakeholders	All employees	TAM TOE
Zhang et al. (2020)	Advances in Civil Engineering	85	China	All project stakeholders	All employees	TOE
Wang et al. (2020a)	Journal of Management in Engineering	177	China	Construction	All employees	TPB
Lee and Yu (2020)	Applied sciences	109	Korea	All project stakeholders	Management	TAM
Wang et al. (2020b)	Journal of Civil Engineering and Management	175	China	Design	All employees	TAM
Okakpu et al. (2020)	Architectural Engineering and Design Management	105	New Zealand	All project stakeholders	All employees	TAM
Xu et al. (2020)	Advances in Civil Engineering	143	China	All project stakeholders	All employees	DIT
Sanchís-Pedregosa et al. (2020)	Journal of Information Technology in Construction	73	Peru	All project stakeholders	All employees	TAM
Ma et al. (2020b)	Journal of Construction Engineering and Management	116	China	All project stakeholders	All employees	Critical success factors(CSF)

Authors and Year of publication	Journal	N	Country	Organization type	Job level	Theories used or factors of influence involved
Yuan et al. (2020)	Sustainability	188	China	Owner	All employees	TOE TAM
Ma et al. (2020a)	Journal of Management in Engineering	151	China	Construction	All employees	TAM
Liao and Teo (2020)	Journal of Civil Engineering and Management	58	Singapore	All project stakeholders	All employees	CSF
Yang (2020)	Master's thesis, Kunming University of Science and Technology	296	China	All project stakeholders	All employees	TAM TOE
Shehzad et al. (2020)	Cham: Springer International Publishing	505	Malaysia	Design	All employees	TOE
Baharuddin et al. (2021)	Collaboration and Integration in Construction, Engineering, Management and Technology	205	Malaysia	All project stakeholders	Management	TAM
Ville-Manzares et al. (2021)	Applied Sciences	92	Spain	All project stakeholders	All employees	Organizational factors
Wu et al. (2021)	International Journal of Environmental Research and Public Health	206	China	All project stakeholders	All employees	TPB
Murguia et al. (2021)	Journal of Construction Engineering and Management	183	Peru	All project stakeholders	All employees	model of systemic BIM adoption(MSBA)
Wang et al. (2021)	Building Research and Information	475	China	All project stakeholders	All employees	DIT TAM
Cui et al. (2021)	Buildings	207	China	Design	All employees	TAM
Cao et al. (2022)	Engineering, Construction and Architectural Management	112	China	All project stakeholders	All employees	DIT
Saka et al. (2024)	Engineering, Construction and Architectural Management	30	Nigeria	All project stakeholders	All employees	INT
Tavallaei et al. (2022)1	Journal of Construction Engineering and Management	98	US	Design	Management	INT
Tavallaei et al. (2022)2	Journal of Construction Engineering and Management	37	US	Engineering and Consulting Services	Management	INT
Tavallaei et al. (2022)3	Journal of Construction Engineering and Management	50	US	Construction	Management	INT
Vigneshwar et al. (2022)	Iranian Journal of Science and Technology, Transactions of Civil Engineering	63	India	All project stakeholders	All employees	TAM
Zhao et al. (2023)	Engineering, Construction and Architectural Management	327	China	Construction	All employees	TAM TOE

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A4 The moderating effects of the national BIM maturity model (8 components) on BIM adoption

Influencing factors	Moderate factors	Subgroups	Main effect estimates					
			K	*r*	95%*CI*		*Q.b*	*P.b*
Psychological factors								
Perceived ease of use	Perceived ease of use→BIM adoption							
	I IV	level 1	2	0.170	-0.245	0.533	30.192	0.000
		level 2	2	0.935	0.849	0.973		
		level 3	16	0.443	0.319	0.551		
		level 4	6	0.417	0.203	0.593		
	II	level 1	2	0.171	-0.236	0.526	31.299	0.000
		level 3	2	0.935	0.851	0.972		
		level 4	22	0.436	0.333	0.528		
	VI	level 1	4	0.719	0.513	0.845	5.531	0.019
		level 2	22	0.436	0.319	0.541		
Technology factors								
Relative Advantage	Relative Advantage→Perceived ease of use							
	I IV	level 3	6	0.422	0.306	0.525	5.841	0.016
		level 4	4	0.181	0.012	0.339		
	III	level 2	6	0.422	0.306	0.525	5.841	0.016
		level 4	4	0.181	0.012	0.339		
	V	level 2	6	0.422	0.306	0.525	5.841	0.016
		level 3	4	0.181	0.012	0.339		
Organizational factors								
Top management support	Top management support→BIM adoption							
	II	level 1	1	0.426	0.052	0.696	13.005	0.001
		level 3	4	0.696	0.563	0.793		
		level 4	21	0.396	0.317	0.469		
	VIII	level 1	3	0.587	0.399	0.728	11.222	0.004
		level 2	2	0.724	0.535	0.843		
		level 3	21	0.396	0.316	0.470		
	Top management support→Perceived ease of use							
	I IV	level 2	2	0.666	0.433	0.815	8.854	0.012
		level 3	6	0.393	0.393	0.538		
		level 4	2	0.095	-0.222	0.393		
	II	level 3	2	0.674	0.419	0.830	5.298	0.021
		level 4	8	0.323	0.156	0.471		
	III	level 1	2	0.666	0.433	0.815	8.854	0.012
		level 2	6	0.393	0.393	0.538		
		level 4	2	0.095	-0.222	0.393		
	V	level 1	2	0.666	0.433	0.815	8.854	0.012
		level 2	6	0.393	0.393	0.538		
		level 3	2	0.095	-0.222	0.393		
	VI	level 1	2	0.674	0.419	0.830	5.298	0.021
		level 2	8	0.323	0.156	0.471		
	VII	level 2	8	0.463	0.337	0.572	5.780	0.016
		level 3	2	0.095	-0.197	0.371		

Influencing factors	Moderate factors	Subgroups	Main effect estimates					
			K	*r*	95%*CI*		*Q.b*	*P.b*
	VIII	level 1	2	0.674	0.419	0.830	5.298	0.021
		level 3	8	0.323	0.156	0.471		
	Top management support→Perceived usefulness							
	I IV	level 2	2	0.734	0.571	0.841		
		level 3	5	0.402	0.250	0.535	9.495	0.009
		level 4	2	0.414	0.169	0.611		
	II	level 3	2	0.729	0.579	0.832	10.677	0.001
		level 4	7	0.406	0.290	0.511		
	III	level 1	2	0.734	0.571	0.841		
		level 2	5	0.402	0.250	0.535	9.495	0.009
		level 4	2	0.414	0.169	0.611		
	V	level 1	2	0.734	0.571	0.841		
		level 2	5	0.402	0.250	0.535	9.495	0.009
		level 3	2	0.414	0.169	0.611		
	VI	level 1	2	0.729	0.579	0.832	10.677	0.001
		level 2	7	0.406	0.290	0.511		
	VIII	level 1	2	0.729	0.579	0.832	10.677	0.001
		level 3	7	0.406	0.290	0.511		
Organizational culture	Organizational culture→BIM adoption							
	III	level 1	3	0.614	0.364	0.781		
		level 2	12	0.364	0.216	0.496	7.283	0.026
		level 4	8	0.608	0.464	0.720		
	Organizational culture→Perceived ease of use							
	I IV	level 2	1	0.952	0.809	0.989		
		level 3	3	0.349	-0.022	0.635	12.599	0.002
		level 4	3	0.631	0.338	0.812		
	II	level 3	1	0.952	0.809	0.989	10.215	0.001
		level 4	6	0.502	0.262	0.683		
	III	level 1	1	0.952	0.809	0.989		
		level 2	3	0.349	-0.022	0.635	12.599	0.002
		level 4	3	0.631	0.338	0.812		
	V	level 1	1	0.952	0.809	0.989		
		level 2	3	0.349	-0.022	0.635	12.599	0.002
		level 3	3	0.631	0.338	0.812		
	VI	level 1	1	0.952	0.809	0.989	10.215	0.001
		level 2	6	0.502	0.262	0.683		
	VIII	level 1	1	0.952	0.809	0.989	10.215	0.001
		level 3	6	0.502	0.262	0.683		
	Organizational culture→Perceived usefulness							
	I IV	level 2	1	0.907	0.801	0.958		
		level 3	2	0.299	0.100	0.475	27.041	0.000
		level 4	3	0.571	0.440	0.679		
	II	level 3	1	0.907	0.752	0.967	11.762	0.001
		level 4	5	0.472	0.298	0.615		

Influencing factors	Moderate factors	Subgroups	Main effect estimates					
			K	*r*	95%*CI*		*Q.b*	*P.b*
	III	level 1	1	0.907	0.801	0.958	27.041	0.000
		level 2	2	0.299	0.100	0.475		
		level 4	3	0.571	0.440	0.679		
	V	level 1	1	0.907	0.801	0.958	27.041	0.000
		level 2	2	0.299	0.100	0.475		
		level 3	3	0.571	0.440	0.679		
	VI	level 1	1	0.907	0.752	0.967	11.762	0.001
		level 2	5	0.472	0.298	0.615		
	VIII	level 1	1	0.907	0.752	0.967	11.762	0.001
		level 3	5	0.472	0.298	0.615		
	Organizational readiness→BIM adoption							
Organizational readiness	I	level 1	1	0.563	0.198	0.791	15.511	0.001
		level 2	2	0.753	0.575	0.863		
		level 3	22	0.329	0.244	0.410		
		level 4	7	0.445	0.298	0.572		
	II	level 1	1	0.563	0.198	0.791	7.527	0.023
		level 3	3	0.641	0.447	0.778		
		level 4	28	0.359	0.280	0.433		
	III	level 1	3	0.695	0.533	0.808	13.655	0.001
		level 2	22	0.330	0.243	0.411		
		level 4	7	0.445	0.296	0.573		
	IV	level 1	1	0.563	0.197	0.791	15.352	0.002
		level 2	2	0.753	0.575	0.863		
		level 3	24	0.335	0.253	0.412		
		level 4	5	0.461	0.289	0.604		
	V	level 1	3	0.695	0.533	0.808	13.655	0.001
		level 2	22	0.330	0.243	0.411		
		level 3	7	0.445	0.296	0.573		
	VI	level 1	3	0.695	0.531	0.809	11.539	0.003
		level 2	28	0.357	0.280	0.429		
		level 4	1	0.364	-0.088	0.692		
	VIII	level 1	3	0.695	0.527	0.811	12.136	0.007
		level 2	1	0.310	-0.158	0.664		
		level 3	25	0.372	0.290	0.448		
		level 4	3	0.245	-0.016	0.475		

Note: I-VIII are the eight components of the BIM Maturity Model. I: Objectives, stages and milestones; II: Champions and drivers; III: Regulatory framework; IV: Noteworthy publications; V: Learning and education; VI: Measurements and benchmarks; VII: Standardised parts and deliverables; VIII: Technology infrastructure.

K= number of studies included in the analysis; *r* = correlations controlling measurement and sampling error; 95%*CI*= the minimum and maximum limits of the 95% confidence interval; *Q.b* = between-group test of homogeneity, with a significant value indicating moderator explains variability

of effect sizes; *P.b* = *p* value of the *Q.b* statistic.

Detailed definitions of the eight components of the BIM Maturity Model and research samples of the criteria for which stage of the BIM Maturity Model they belong to are from Succar and Kassem (2015).

A5 The moderating effect of contextual factors (including job level, organization type and time span) on BIM adoption

Influencing factors	Moderate factor	Subgroups	Main effect estimates					
			K	*r*	95%*CI*		*Q.b*	*P.b*
Psychological factors								
Perceived ease of use	Perceived ease of use→BIM adoption							
	Job level	All employees	22	0.393	0.285	0.490	22.358	0.000
		Management	4	0.828	0.710	0.901		
Technology factors								
Relative Advantage	Relative Advantage→BIM adoption							
	Time Span	Before 2016	9	0.499	0.42	0.57	5.411	0.020
		After 2016	17	0.332	0.203	0.449		
Compatibility	Compatibility→BIM adoption							
	Job level	All employees	19	0.432	0.303	0.546	7.691	0.021
		Management	4	0.489	0.200	0.700		
		General employees	2	-0.193	-0.574	0.257		
	Compatibility→Perceived usefulness							
	Job level	All employees	11	0.569	0.451	0.668	15.789	0.000
		Management	2	0.911	0.809	0.959		
Organizational factors								
Top management support	Top management support→Perceived ease of use							
	Job level	All employees	8	0.300	0.172	0.417	14.315	0.000
		Management	2	0.744	0.572	0.057		
Organizational culture	Organizational culture→Perceived ease of use							
	Job level	All employees	4	0.379	0.014	0.654	6.392	0.011
		Management	3	0.822	0.612	0.924		
	Organization type	All project stakeholders	3	0.846	0.736	0.912	21.253	0.000
		Construction	4	0.321	0.088	0.520		
	Time Span	Before 2016	3	0.792	0.509	0.921	3.106	0.078
		After 2016	4	0.436	0.029	0.72		
	Organizational culture→Perceived usefulness							
	Job level	All employees	4	0.403	0.218	0.560	13.198	0.000
		Management	2	0.811	0.670	0.896		
	Organization type	All project stakeholders	3	0.740	0.587	0.842	9.005	0.003
		Construction	3	0.352	0.106	0.557		
	Time Span	Before 2016	3	0.724	0.51	0.853	4.068	0.044
		After 2016	3	0.39	0.071	0.636		
Environmental factors								
Coercive pressures	Coercive pressures→BIM adoption							
	Job level	All employees	12	0.373	0.231	0.500	6.482	0.039
		Management	4	0.278	0.020	0.502		
		General employees	2	-0.129	-0.432	0.237		
	Organization type	All project stakeholders	11	0.341	0.199	0.469	8.288	0.040
		construction	4	0.303	0.069	0.506		
		Engineering and Consulting Services	2	-0.144	-0.463	0.207		
		owner	1	0.560	0.141	0.809		

Influencing factors	Moderate factor	Subgroups	Main effect estimates					
			K	*r*	95%*CI*		*Q.b*	*P.b*
Coercive pressures	Coercive pressures→Perceived ease of use							
	Organization type	All project stakeholders	3	0.152	0.035	0.265	11.766	0.003
		Construction	2	0.158	0.061	0.251		
		owner	1	0.415	0.289	0.527		

K= number of studies included in the analysis; *r* = correlations controlling measurement and sampling error; 95%*CI*= the minimum and maximum limits of the 95% confidence interval; *Q.b* = between-group test of homogeneity, with a significant value indicating moderator explains variability of effect sizes; *P.b* = *p* value of the *Q.b* statistic.

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