APPENDICES

Appendix A: Statistical Tables

Table A 1 Unidimensionality and Reliability of BIM Adoption

Items	BA	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
BIM technologies are a fundamental tool guiding our project management and decision-making.	0.816	0.675	0.574	0.746	
Our organization has seamlessly integrated BIM technologies into our routine project practices.	0.815	0.678	0.569	0.747	
Our organization is at BIM Level 1 (combining 2D and 3D CAD models).	0.760	0.565	0.384	0.772	
Our organization is at BIM Level 0 (2D CAD drawings and paper-based communication).	0.712	0.610	0.442	0.762	0.803
Our organization is at BIM Level 2 (collaborative federated BIM models).	0.626	0.471	0.236	0.795	
Our organization is at BIM Level 3 (full integration with a single shared model among project participants).	0.549	0.400	0.191	0.811	

Table A 2 Final Conceptual Model Indicator Variables for the BIM Adoption (BA) Construct

Latent Component	Indicator Variable	Measurement Variable	Label
BIM Adoption	BA2	BIM technologies are a fundamental tool guiding our project management and decision-making.	BA1
	BA1	Our organization has seamlessly integrated BIM technologies into our routine project practices.	BA2
	BA4	Our organization is at BIM Level 1 (combining 2D and 3D CAD models).	BA3
	BA3	Our organization is at BIM Level 0 (2D CAD drawings and paper-based communication).	BA4

BA5	Our organization is at BIM Level 2 (collaborative federated BIM models).	BA5

Table A 3 Factor Loading and P-Value of the BIM Adoption (BA) Construct

Hypothesised relationships (Path)	Unstandardised Coefficient (λ)	Standardised Coefficient (λ)	P-Value	R- Square	Significant at 5% Level
BA1 ← BA	1.000	0.825	0.00	0.681	Yes
BA2 ← BA	0.960	0.830	0.00	0.689	Yes
BA3 ← BA	0.689	0.562	0.00	0.316	Yes
BA4 ← BA	0.770	0.651	0.00	0.424	Yes
BA5 ← BA	0.675	0.507	0.00	0.257	Yes

Table A 4 Unidimensionality and Reliability of BIM Awareness

Items	C	B	SR	PP	Corrected Item-Total Correlation.	Squared Multiple Correlation.	Cronbach's Alpha
I am aware that BIM represents the future of managing project information in construction.	0.880				0.793	0.720	0.968
I am aware of how BIM significantly changes the traditional workflow in the construction industry.	0.872				0.837	0.763	
I am aware that BIM is more than 3D modelling; it involves managing project information.	0.863				0.738	0.740	
I am aware that BIM is all about real-time collaboration throughout a project's lifecycle.	0.841				0.869	0.815	
I hear more about BIM in industry discussions now than in the past.	0.834				0.726	0.666	

Items	C	B	SR	PP	Corrected Item-Total Correlation.	Squared Multiple Correlation.	Cronbach's Alpha
I am aware of BIM maturity levels and their implications for project collaboration.	0.829				0.763	0.741	
I am aware of the concept of BIM.	0.812				0.855	0.796	
I am aware of the difference between BIM and traditional 3D CAD systems.	0.807				0.773	0.718	
I am aware that BIM improves the quality of construction outcomes.		0.912			0.848	0.795	
I am aware that BIM helps improve the overall visualization of a construction project.		0.911			0.849	0.831	
I am aware that BIM enhances communication and coordination between project stakeholders.		0.893			0.840	0.830	0.812
I am aware that BIM reduces errors and the need for rework in construction projects.		0.874			0.857	0.827	
I am aware that BIM helps detect clashes in designs.		0.872			0.767	0.735	
I am aware that BIM allows faster and more efficient decision-making in project execution.		0.871			0.807	0.782	

Items	C	B	SR	PP	Corrected Item-Total Correlation.	Squared Multiple Correlation.	Cronbach's Alpha
I am aware that BIM helps in reducing project costs.		0.804			0.818	0.778	
I am aware of BIM roadmaps for implementation in the construction industry.			0.953		0.672	0.834	
I am familiar with international BIM standards.			0.857		0.719	0.891	0.825
I am aware that following BIM roadmaps is important for successful implementation.			0.696		0.790	0.784	
I am aware that BIM is used during the construction phase to monitor progress and detect clashes.				0.764	0.507	0.608	
I am aware that BIM can be applied during the design phase for 3D visualizations and simulations.				0.681	0.622	0.808	0.800
I know that BIM can be used for facility management after project completion.				0.517	0.614	0.590	

Table A 5 Final Conceptual Model Indicator Variables for the BIM Awareness Construct

Latent Component	Indicator Variable	Measurement Variable	Label
Concepts (C)		I am aware that BIM represents the future of managing project information in construction.	C1

Latent Component	Indicator Variable	Measurement Variable	Label
		I am aware of how BIM significantly changes the traditional workflow in the construction industry.	C2
		I am aware that BIM is more than 3D modelling; it involves managing project information.	C3
		I am aware that BIM is all about real-time collaboration throughout a project's lifecycle.	C4
		I hear more about BIM in industry discussions now than in the past.	C5
		I am aware of BIM maturity levels and their implications for project collaboration.	C6
		I am aware of the concept of BIM.	C7
		I am aware of the difference between BIM and traditional 3D CAD systems.	C8
Benefits (B)		I am aware that BIM improves the quality of construction outcomes.	B1
		I am aware that BIM helps improve the overall visualization of a construction project.	B2
		I am aware that BIM enhances communication and coordination between project stakeholders.	B3
		I am aware that BIM reduces errors and the need for rework in construction projects.	B4
		I am aware that BIM helps in detection of clashes in designs.	B5
		I am aware that BIM allows faster and more efficient decision-making in project execution.	B6
		I am aware that BIM helps in reducing project costs.	B7
Standards and roadmaps (SR)		I am aware of BIM roadmaps for implementation in the construction industry	SR1
		I am familiar with international BIM standards.	SR2
		I believe that following BIM roadmaps is important for successful implementation.	SR3
Project Phase (PP)		I am aware that BIM is used during the construction phase to monitor progress and detect clashes.	PP1
		I am aware that BIM can be applied during the design phase for 3D visualizations and simulations.	PP2

Latent Component	Indicator Variable	Measurement Variable	Label
		I know that BIM can be used for facility management after project completion.	PP3

Table A 6 Factor Loading and P-Value of the BIM Awareness Construct

Hypothesised relationships (Path)	Unstandardised Coefficient (λ)	Standardised Coefficient (λ)	P-Value	R- Square	Significant at 5% Level
C1 ← C	1.000	0.894	0.00	0.800	Yes
C2 ← C	0.889	0.889	0.00	0.789	Yes
C3 ← C	0.907	0.873	0.00	0.763	Yes
C4 ← C	0.930	0.816	0.00	0.666	Yes
C5 ← C	0.918	0.819	0.00	0.670	Yes
C6 ← C	0.945	0.812	0.00	0.659	Yes
C7 ← C	0.997	0.821	0.00	0.674	Yes
C8 ← C	0.961	0.791	0.00	0.626	Yes
B1 ← B	1.000	0.912	0.00	0.832	Yes
B2 ← B	1.000	0.904	0.00	0.817	Yes
B3 ← B	0.994	0.898	0.00	0.806	Yes
B4 ← B	0.981	0.884	0.00	0.781	Yes
B5 ← B	1.018	0.871	0.00	0.758	Yes
B6 ← B	1.008	0.864	0.00	0.747	Yes
B7 ← B	0.996	0.802	0.00	0.643	Yes
PP1 ← PP	1.000	0.803	0.00	0.646	Yes
PP2 ← PP	0.665	0.618	0.00	0.381	Yes
PP3 ← PP	0.610	0.540	0.00	0.291	Yes
SR1 ← SR	1.000	0.928	0.00	0.861	Yes
SR2 ← SR	0.905	0.858	0.00	0.737	Yes
SR3 ← SR	0.641	0.738	0.00	0.545	Yes

Table A 7 Unidimensionality and Reliability of BIM Knowledge

Items	F	IP	TK	ABK	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha
I know how to export/import BIM data using various file formats.	0.952				0.862	0.816	
I can manipulate 3D models using BIM software	0.925				0.875	0.865	0.981
I can generate automatic schedules and quantities using BIM tools.	0.914				0.834	0.825	

Items	F	IP	TK	ABK	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha
I am proficient in using BIM software.	0.885				0.849	0.863	
I can run clash detection using BIM software.	0.856				0.892	0.895	
I understand the steps required to implement BIM on a project.		0.965			0.923	0.919	
I know how to work collaboratively with other disciplines using a BIM model.		0.958			0.908	0.868	0.802
I am familiar with developing and following a BIM Execution Plan (BEP).		0.935			0.929	0.907	
I have gained practical experience by working on BIM projects.			0.915		0.866	0.814	
I have received formal training in BIM software and processes.			0.902		0.895	0.854	0.812
My organization provides opportunities for continuous BIM training and development.			0.846		0.831	0.772	
I am familiar with the integration of BIM with emerging technologies, such as virtual reality (VR) and augmented reality (AR).				0.969	0.867	0.862	0.889
I know the concept of Digital Twins and its relationship with BIM for real-time				0.945	0.869	0.886	

Items	F	IP	TK	ABK	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha
data management and simulation.							
I understand how 4D BIM (scheduling) and 5D BIM (estimating) are applied in construction projects.				0.923	0.889	0.900	

Table A 8 Final Conceptual Model Indicator Variables for BIM Knowledge Construct

Latent Component	Indicator Variable	Measurement Variable	Label
Fundamentals of BIM (F)		I know how to export/import BIM data using various file formats.	F1
		I can manipulate 3D models using BIM software	F2
		I can generate automatic schedules and quantities using BIM tools.	F3
		I am proficient in using BIM software.	F4
		I can run clash detection using BIM software.	F5
BIM Implementation in Projects (IP)		I understand the steps required to implement BIM on a project.	TK1
		I know how to work collaboratively with other disciplines using a BIM model.	TK2
		I am familiar with developing and following a BIM Execution Plan (BEP).	TK3
Training and Knowledge Acquisition in BIM (TK)		I have gained practical experience by working on BIM projects.	ABK1
		I have received formal training in BIM software and processes.	ABK2
		My organization provides opportunities for continuous BIM training and development.	ABK3
Advanced BIM Knowledge (ABK)		I am familiar with the integration of BIM with emerging technologies, such as virtual reality (VR) and augmented reality (AR).	IP1

Latent Component	Indicator Variable	Measurement Variable	Label
		I know the concept of Digital Twins and its relationship with BIM for real-time data management and simulation.	IP2
		I understand how 4D BIM (scheduling) and 5D BIM (estimating) are applied in construction projects.	IP3

Table A 9 Factor Loading and P-Value of BIM Knowledge Construct

Hypothesised relationships (Path)	Unstandardised Coefficient (λ)	Standardised Coefficient (λ)	P-Value	R- Square	Significant at 5% Level
F1 ← F	1.000	0.952	0.00	0.907	Yes
F2 ← F	0.979	0.927	0.00	0.860	Yes
F3 ← F	1.002	0.903	0.00	0.815	Yes
F4 ← F	0.957	0.896	0.00	0.802	Yes
F5 ← F	0.870	0.854	0.00	0.729	Yes
TK1 ← TK	1.000	0.909	0.00	0.826	Yes
TK2 ← TK	0.959	0.890	0.00	0.792	Yes
TK3 ← TK	1.011	0.866	0.00	0.751	Yes
ABK1 ← ABK	1.000	0.954	0.00	0.910	Yes
ABK2 ← ABK	0.995	0.961	0.00	0.924	Yes
ABK3 ← ABK	1.018	0.920	0.00	0.846	Yes
IP1 ← IP	1.000	0.966	0.00	0.933	Yes
IP2 ← IP	1.029	0.956	0.00	0.915	Yes
IP3 ← IP	0.990	0.936	0.00	0875	Yes

Table A 10 Final Conceptual Model Indicator Variables for the Organisational and Technological Readiness

Latent Component	Indicator Variable	Measurement Variable	Label
BIM Capability and Integration (BCI)		Our organization employs professionals with specialized skills and expertise in utilizing BIM.	BCI1
		Our workforce is skilled at using BIM to facilitate communication and data sharing between various stakeholders in a project.	BCI2
		A significant portion of our workforce has received formal BIM training or certifications.	BCI3
		Our organization has enough staff with the required skills to implement BIM.	BCI4
		Our project management processes are adapted to accommodate BIM.	BCI5

Latent Component	Indicator Variable	Measurement Variable	Label
		BIM technologies are integrated into both the design and construction stages of our project workflow.	BCI6
		BIM technologies are integrated into every stage of our project workflow, from design to construction and beyond.	BCI7
		The use of BIM tools is an integral part of our project planning.	BCI8
		Our organization encourages cross-disciplinary collaboration among different departments for BIM implementation.	BCI9
		Our workforce understands how to use BIM for better coordination between different project teams.	BCI10
		Our organization offers employees regular in-house training sessions on BIM.	BCI11
		There is a systematic approach in place for monitoring and evaluating the progress of BIM implementation within our organization.	BCI12
		Our workforce is capable of collaborating effectively across disciplines (e.g., architects, engineers, contractors) in BIM projects.	BCI13
BIM Infrastructure and Skills Development (BISD)		We have established systems for secure and efficient data sharing and collaboration.	BISD1
		Our organization has a reliable IT infrastructure capable of handling the demands of BIM software efficiently.	BISD2
		We regularly invest in upgrading our technological infrastructure to support the seamless integration of BIM related technologies.	BISD3
		Our organization has a dedicated IT or technical support team.	BISD4
		Our organization has invested in the latest BIM software to support project workflows.	BISD5
		BIM training in our organization is mostly self-led by employees.	BISD6
		Employees are encouraged and supported to pursue professional BIM certification programs.	BISD7

Latent Component	Indicator Variable	Measurement Variable	Label
		The effectiveness of our BIM training programs is measured through feedback and improved application of learned skills.	BISD8
BIM Leadership and Strategic Alignment (BLSA)		Our management believes that BIM will lead to long-term benefits despite the initial challenges of implementation.	BLSA1
		Our management fosters a culture of innovation that supports the adoption of BIM across all levels of the organization.	BLSA2
		Senior management in our organization is committed to adopting new technologies like BIM.	BLSA3
		The implementation of BIM aligns with our organization's long-term goals.	BLSA4
		Our organization has a clearly defined and documented strategy for the implementation of BIM.	BLSA5

Table A 11 Unidimensionality of Organisational and Technological Readiness

Items	BCI	BISD	BLSA	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha
Our organization employs professionals with specialized skills and expertise in utilizing BIM.	0.785			0.702	0.799	
Our workforce is skilled at using BIM to facilitate communication and data sharing between various stakeholders in a project.	0.741			0.670	0.783	
A significant portion of our workforce has received formal BIM training or certifications.	0.731			0.717	0.832	0.985
Our organization has enough staff with the required skills to implement BIM.	0.729			0.850	0.827	
Our project management processes are adapted to accommodate BIM.	0.712			0.770	0.834	

Items	BCI	BISD	BLSA	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha
BIM technologies are integrated into both the design and construction stages of our project workflow.	0.703			0.893	0.870	
BIM technologies are integrated into every stage of our project workflow, from design to construction and beyond.	0.700			0.676	0.607	
The use of BIM tools is an integral part of our project planning.	0.691			0.844	0.861	
Our organization encourages cross-disciplinary collaboration among different departments for BIM implementation.	0.678			0.785	0.804	
Our workforce understands how to use BIM for better coordination between different project teams.	0.676			0.910	0.904	
Our organization offers employees regular in-house training sessions on BIM.	0.667			0.897	0.911	
Our organization provides access to external BIM training programs to enhance the BIM-related skills of our workforce.	0.655			0.893	0.872	
There is a systematic approach in place for monitoring and evaluating the progress of BIM implementation within our organization.	0.611			0.844	0.832	
Our workforce is capable of collaborating effectively across disciplines (e.g., architects, engineers,	0.595			0.896	0.892	

Items	BCI	BISD	BLSA	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha
contractors) in BIM projects.						
We have established systems for secure and efficient data sharing and collaboration.		0.833		0.925	0.928	
Our organization has a reliable IT infrastructure capable of handling the demands of BIM software efficiently.		0.822		0.862	0.855	
We regularly invest in upgrading our technological infrastructure to support the seamless integration of BIM related technologies.		0.731		0.878	0.900	
Our organization has a dedicated IT or technical support team.		0.725		0.893	0.907	
Our organization has invested in the latest BIM software to support project workflows.		0.648		0.894	0.925	
BIM training in our organization is mostly self-led by employees.		0.570		0.881	0.889	
Employees are encouraged and supported to pursue professional BIM certification programs.		0.550		0.668	0.706	
The effectiveness of our BIM training programs is measured through feedback and improved application of learned skills.		0.537		0.830	0.843	
Our management believes that BIM will lead to long-term benefits despite the			0.829	0.865	0.797	

Items	BCI	BISD	BLSA	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha
initial challenges of implementation						
Our management fosters a culture of innovation that supports the adoption of BIM across all levels of the organization.			0.826	0.874	0.892	
Senior management in our organization is committed to adopting new technologies like BIM.			0.802	0.881	0.919	
The implementation of BIM aligns with our organization's long-term goals.			0.769	0.845	0.920	
Our organization has a clearly defined and documented strategy for the implementation of BIM.			0.569	0.853	0.915	
BIM technologies are integrated into only the design stage of our project workflows.						

Table A 12 Factor Loading and P-Value of the Organisational and Tech. Readiness

Hypothesised relationships (Path)	Unstandardised Coefficient (λ)	Standardised Coefficient (λ)	P-Value	R- Square	Significant at 5% Level
BCI1 ← BCI	1.000	0.917	0.00	0.840	Yes
BCI2 ← BCI	1.025	0.950	0.00	0.903	Yes
BCI3 ← BCI	1.022	0.918	0.00	0.842	Yes
BCI4 ← BCI	0.950	0.894	0.00	0.799	Yes
BCI5 ← BCI	0.943	0.924	0.00	0.853	Yes
BCI6 ← BCI	0.920	0.863	0.00	0.744	Yes
BCI7 ← BCI	0.912	0.818	0.00	0.669	Yes
BCI8 ← BCI	0.981	0.915	0.00	0.837	Yes
BCI9 ← BCI	1.026	0.913	0.00	0.833	Yes
BCI10← BCI	0.986	0.910	0.00	0.829	Yes
BCI11← BCI	1.080	0.901	0.00	0.812	Yes
BCI12 ← BCI	0.913	0.888	0.00	0.788	Yes
BCI13 ← BCI	0.897	0.852	0.00	0.726	Yes

Hypothesised relationships (Path)	Unstandardised Coefficient (λ)	Standardised Coefficient (λ)	P-Value	R- Square	Significant at 5% Level
BISD1 ← BISD	1.000	0.931	0.00	0.867	Yes
BISD2 ← BISD	0.967	0.914	0.00	0.835	Yes
BISD3 ← BISD	1.015	0.943	0.00	0.890	Yes
BISD4 ← BISD	0.916	0.880	0.00	0.774	Yes
BISD5 ← BISD	0.969	0.917	0.00	0.840	Yes
BISD6 ← BISD	0.670	0.714	0.00	0.510	Yes
BISD7 ← BISD	0.818	0.832	0.00	0.692	Yes
BISD8← BISD	0.812	0.852	0.00	0.726	Yes
BLSA1 ← BLSA	1.000	0.875	0.00	0.765	Yes
BLSA2 ← BLSA	1.032	0.899	0.00	0.809	Yes
BLSA3 ← BLSA	1.062	0.877	0.00	0.769	Yes
BLSA4 ← BLSA	1.022	0.909	0.00	0.826	Yes
BLSA5 ← BLSA	0.970	0.830	0.00	0.690	Yes

Table A 13 Unidimensionality of Key Drivers Influencing BIM Adoption

Items	KD	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
The capability of BIM to manage project data more efficiently is a significant factor in its adoption.	0.929	0.568	0.689	0.976	0.974
BIM's ability to reduce project risks by identifying potential issues early in the design phase drives adoption.	0.926	0.605	0.681	0.976	
The growing industry trend toward digital transformation has prompted our organization to embrace BIM as a competitive advantage.	0.915	0.864	0.906	0.972	
BIM's ability to improve collaboration between different project stakeholders drives our organization to adopt it.	0.914	0.864	0.913	0.972	
BIM's capability to improve decision-making has motivated our organization to integrate these technologies.	0.910	0.851	0.795	0.972	
The overall improvement in construction project quality due to BIM is a key driver for adoption.	0.909	0.792	0.769	0.973	

Items	KD	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
BIM's capability to reduce errors has motivated our organization to integrate these technologies.	0.902	0.843	0.808	0.972	
BIM's ability to streamline workflows and improve collaboration is a key driver for adoption.	0.900	0.899	0.864	0.971	
The increasing availability of BIM training programs and certification for our workforce motivates BIM adoption.	0.893	0.866	0.855	0.972	
BIM adoption provides a competitive edge in winning new construction projects.	0.861	0.903	0.882	0.971	
The efficiency gains associated with BIM motivates us to adopt it.	0.859	0.896	0.871	0.971	
The potential for long-term return on investment (ROI) from BIM adoption is a key driver.	0.852	0.878	0.897	0.972	
BIM's potential to reduce project costs motivates us to adopt it.	0.847	0.863	0.864	0.972	
The demand from clients for BIM-based project delivery motivates us to adopt BIM.	0.746	0.873	0.875	0.972	
Government incentives have played a significant role in encouraging BIM adoption within our organization.	0.547	0.867	0.883	0.972	
Regulatory policies have played a significant role in encouraging BIM adoption within our organization.	0.508	0.885	0.883	0.972	

Table A 14 Final Conceptual Model Indicator Variables for Key Drivers Influencing BIM Adoption Construct

Latent Component	Indicator Variable	Measurement Variable	Label
Key Drivers Influencing BIM Adoption (KD)		The capability of BIM to manage project data more efficiently is a significant factor in its adoption.	KD1
		BIM's ability to reduce project risks by identifying potential issues early in the design phase drives adoption.	KD2
		The growing industry trend toward digital transformation has prompted our organization to embrace BIM as a competitive advantage	KD3
		BIM's ability to improve collaboration between different project stakeholders drives our organization to adopt it.	KD4
		BIM's capability to improve decision-making has motivated our organization to integrate these technologies.	KD5
		The overall improvement in construction project quality due to BIM is a key driver for adoption.	KD6
		BIM's capability to reduce errors has motivated our organization to integrate these technologies.	KD7
		BIM's ability to streamline workflows and improve collaboration is a key driver for adoption.	KD8
		The increasing availability of BIM training programs and certification for our workforce motivates BIM adoption	KD9
		BIM adoption provides a competitive edge in winning new construction projects.	KD10
		The efficiency gains associated with BIM technologies motivates us to adopt it.	KD11
		The potential for long-term return on investment (ROI) from BIM adoption is a key driver.	KD12
		BIM's potential to reduce project costs motivates us to adopt it.	KD13
		The demand from clients for BIM-based project delivery motivates us to adopt BIM.	KD14
		Government incentives have played a significant role in encouraging BIM adoption within our organization.	KD15
		Regulatory policies have played a significant role in encouraging BIM adoption within our organization.	KD16

Table A 15 Factor Loading and P-Value of Key Drivers Influencing BIM Adoption Construct

Hypothesised relationships (Path)	Unstandardised Coefficient (λ)	Standardised Coefficient (λ)	P-Value	R- Square	Significant at 5% Level
KD1 ← KD	1.000	0.929	0.00	0.862	Yes
KD2 ← KD	1.003	0.926	0.00	0.858	Yes
KD3 ← KD	1.051	0.915	0.00	0.838	Yes
KD4 ← KD	0.987	0.914	0.00	0.836	Yes
KD5 ← KD	0.986	0.910	0.00	0.828	Yes
KD6 ← KD	0.958	0.909	0.00	0.827	Yes
KD7 ← KD	0.966	0.902	0.00	0.814	Yes
KD8 ← KD	0.933	0.900	0.00	0.811	Yes
KD9 ← KD	1.002	0.893	0.00	0.798	Yes
KD10 ← KD	0.936	0.861	0.00	0.742	Yes
KD11 ← KD	0.973	0.859	0.00	0.737	Yes
KD12 ← KD	0.914	0.852	0.00	0.727	Yes
KD13 ← KD	0.968	0.847	0.00	0.718	Yes
KD14 ← KD	0.942	0.746	0.00	0.556	Yes
KD15← KD	0.690	0.547	0.00	0.300	Yes
KD16 ← KD	0.620	0.508	0.00	0.258	Yes

Table A 16 Unidimensionality of Key Barriers Influencing BIM Adoption

Items	IEB	TOB	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Lack of government regulations to support implementation of BIM	0.862		0.663	0.782	0.980	0.980
Lack of a government mandate for BIM implantation.	0.837		0.760	0.813	0.980	
Lack of demand and interest from the clients on the application of BIM in their projects.	0.814		0.779	0.796	0.980	
High cost of Data to operate cloud-based BIM	0.762		0.824	0.837	0.979	
Lack of training courses for industry professionals	0.752		0.795	0.844	0.979	
The initial cost of the technology required for BIM implementation	0.736		0.807	0.868	0.979	

Items	IEB	TOB	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Lack of IT infrastructure	0.722		0.843	0.832	0.979	
Lack of skilled professionals with BIM expertise.	0.722		0.857	0.859	0.979	
The industry's cultural resistance to change	0.717		0.844	0.860	0.979	
Cost of BIM education and training	0.688		0.790	0.783	0.979	
Lack of senior management buy-in	0.660		0.825	0.794	0.979	
Lack of case studies that have implemented BIM and realized positive return on investment (ROI)	0.647		0.845	0.818	0.979	
Limited awareness among organizational leadership about the potential benefits of BIM.	0.602		0.843	0.800	0.979	
Lack of awareness of BIM by industry stakeholders	0.556		0.830	0.794	0.979	
The steep learning curve to develop BIM expertise		0.851	0.810	0.799	0.979	
Lack of standard contract to deal with responsibility/risk assignment and BIM ownership.		0.801	0.859	0.847	0.979	0.981
Unavailability of BIM risk insurance		0.800	0.848	0.847	0.979	
Low computer skills among construction professionals.		0.792	0.844	0.860	0.979	
Non-adoption of BIM by other		0.791	0.836	0.844	0.979	

Items	IEB	TOB	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
industry professionals						
Data security issues		0.790	0.840	0.846	0.979	
Lack of industry BIM standards and guidelines for implementation		0.716	0.783	0.820	0.980	
Data interoperability challenges between various BIM software.		0.705	0.837	0.856	0.979	
Lack of project funding to support BIM		0.692	0.854	0.880	0.979	
The reluctance of other project parties to share information		0.664	0.710	0.790	0.980	

Table A 17 Final Conceptual Model Indicator Variables for Key Barriers Influencing BIM Adoption Construct

Latent Component	Indicator Variable	Measurement Variable	Label
Institutional and Economic Barriers (IEB)		Lack of government regulations to support the implementation of BIM.	IEB1
		Lack of a government mandate for BIM implantation.	IEB2
		Lack of demand and interest from the clients in the application of BIM in their projects.	IEB3
		High cost of Data to operate cloud-based BIM	IEB4
		Lack of training courses for industry professionals	IEB5
		The initial cost of the technology required for BIM implementation	IEB6
		Lack of IT infrastructure	IEB7
		Lack of skilled professionals with BIM expertise.	IEB8
		The industry's cultural resistance to change	IEB9
		Cost of BIM education and training	IEB10
		Lack of senior management buy-in	IEB11
		Lack of case studies that have implemented BIM and realized positive return on investment (ROI)	IEB12

Latent Component	Indicator Variable	Measurement Variable	Label
		Limited awareness among organizational leadership about the potential benefits of BIM.	IEB14
Technical and Operational Barriers (TOB)		The steep learning curve to develop BIM expertise	TOB1
		Lack of standard contract to deal with responsibility/risk assignment and BIM ownership.	TOB2
		Unavailability of BIM risk insurance	TOB3
		Low computer skills among construction professionals.	TOB4
		Non-adoption of BIM by other industry professionals	TOB5
		Data security issues	TOB6
		Lack of industry BIM standards and guidelines for implementation	TOB7
		Data interoperability challenges between various BIM software	TOB8
		Lack of project funding to support BIM	TOB9
		The reluctance of other project parties to share information	TOB10

Table A 18 Factor Loading and P-Value of Key Barriers Influencing BIM Adoption Construct

Hypothesised relationships (Path)	Unstandardised Coefficient (λ)	Standardised Coefficient (λ)	P-Value	R-Square	Significant at 5% Level
IEB1 ← IEB	1.000	0.872	0.00	0.760	Yes
IEB2 ← IEB	0.962	0.852	0.00	0.726	Yes
IEB3 ← IEB	0.999	0.867	0.00	0.752	Yes
IEB4 ← IEB	1.004	0.898	0.00	0.806	Yes
IEB5 ← IEB	0.979	0.861	0.00	0.742	Yes
IEB6 ← IEB	1.026	0.882	0.00	0.778	Yes
IEB7 ← IEB	0.970	0.874	0.00	0.764	Yes
IEB8 ← IEB	0.996	0.871	0.00	0.759	Yes
IEB9 ← IEB	0.939	0.819	0.00	0.671	Yes
IEB10 ← IEB	1.003	0.866	0.00	0.749	Yes
IEB11 ← IEB	0.894	0.774	0.00	0.599	Yes
IEB12 ← IEB	0.903	0.833	0.00	0.694	Yes
IEB13 ← IEB	0.821	0.685	0.00	0.470	Yes
IEB14 ← IEB	0.855	0.755	0.00	0.570	Yes
TOB1 ←TOB	1.000	0.924	0.00	0.855	Yes
TOB2 ← TOB	0.995	0.906	0.00	0.822	Yes
TOB3 ← TOB	0.980	0.905	0.00	0.820	Yes
TOB4 ← TOB	0.947	0.800	0.00	0.639	Yes
TOB5 ← TOB	0.900	0.901	0.00	0.811	Yes
TOB6 ← TOB	1.013	0.858	0.00	0.736	Yes
TOB7 ← TOB	0.871	0.873	0.00	0.762	Yes

Hypothesised relationships (Path)	Unstandardised Coefficient (λ)	Standardised Coefficient (λ)	P-Value	R-Square	Significant at 5% Level
TOB8 ← TOB	0.947	0.871	0.00	0.758	Yes
TOB9 ← TOB	0.910	0.830	0.00	0.690	Yes
TOB10 ← TOB	0.927	0.869	0.00	0.755	Yes

Table A 19 Unidimensionality of the Impact of BIM on Construction Project Performance

Items	PEPO	QCSE	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
The utilization of BIM technologies has led to improved accuracy in our project planning and estimation	0.826		0.783	0.682	0.982	
BIM implementation has led to substantial cost savings for our organization by streamlining work processes	0.806		0.838	0.806	0.982	
BIM-enabled simulations and visualizations have positively impacted stakeholder communication and understanding of project progress	0.801		0.871	0.818	0.981	0.982
The integration of BIM technologies has contributed to the timely completion of projects by our organization	0.791		0.890	0.845	0.981	
Our organization has observed a significant reduction in rework since implementing BIM	0.787		0.867	0.809	0.981	
Our organization has observed improved budget adherence across our projects	0.782		0.892	0.865	0.981	

Items	PEPO	QCSE	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
with the integration of BIM						
Our organization has observed an improvement in our workflow due to the implementation of BIM	0.746		0.897	0.847	0.981	
BIM has played a crucial role in optimizing construction sequencing and planning within our organization	0.732		0.869	0.810	0.981	
We have witnessed a significant improvement in tracking change orders throughout our project with the implementation of BIM	0.721		0.904	0.857	0.981	
Our organization has witnessed a marked reduction in errors since integrating BIM into our processes	0.665		0.920	0.877	0.981	
BIM adoption has enhanced coordination among project teams, leading to smoother project execution	0.615		0.907	0.836	0.981	
BIM has significantly improved our quality control measures, allowing us to detect and address potential issues early in the project lifecycle		0.871	0.913	0.931	0.981	0.981
With the integration of BIM, our organization has		0.816	0.847	0.788	0.982	

Items	PEPO	QCSE	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
made significant strides in reducing our environmental footprint						
Our organization has witnessed tangible improvements in the energy efficiency of our projects through the integration of BIM		0.778	0.825	0.767	0.982	
Our organization has experienced a notable reduction in accidents on construction sites since implementing		0.761	0.835	0.785	0.982	
BIM has enabled real-time monitoring of safety conditions during our projects, providing us with invaluable insights to proactively address safety concerns and ensure the well-being of our workforce		0.759	0.820	0.732	0.982	
BIM-enabled simulations have facilitated improved material selection within our organization, allowing us to make more informed choices that prioritize sustainability		0.724	0.877	0.863	0.981	

Table A 27 Final Conceptual Model Indicator Variables for the Impact of BIM on Construction Project Performance Construct

Latent Component	Indicator Variable	Measurement Variable	Label
Project Efficiency and Performance Optimization (PEPO)		The utilization of BIM technologies has led to improved accuracy in our project planning and estimation	PEPO1
		BIM implementation has led to substantial cost savings for our organization by streamlining work processes	PEPO2
		BIM-enabled simulations and visualizations have positively impacted stakeholder communication and understanding of project progress	PEPO3
		The integration of BIM technologies has contributed to the timely completion of projects by our organization	PEPO4
		Our organization has observed a significant reduction in rework since implementing BIM	PEPO5
		Our organization has observed improved budget adherence across our projects with the integration of BIM	PEPO6
		Our organization has observed an improvement in our workflow due to the implementation of BIM	PEPO7
		BIM has played a crucial role in optimizing construction sequencing and planning within our organization	PEPO8
		We have witnessed a significant improvement in tracking change orders throughout our project with the implementation of BIM	PEPO9
		Our organization has witnessed a marked reduction in errors since integrating BIM into our processes	PEPO10
		BIM adoption has enhanced coordination among project teams, leading to smoother project execution	PEPO11
Quality Control and Sustainability Enhancements (QCSE)		BIM has significantly improved our quality control measures, allowing us to detect and address potential issues early in the project lifecycle	QCSE1
		With the integration of BIM, our organization has made significant strides in reducing our environmental footprint.	QCSE2
		Our organization has witnessed tangible improvements in the energy efficiency of our projects through the integration of BIM.	QCSE3
		Our organization has experienced a notable reduction in accidents on construction sites since implementing.	QCSE4
		BIM has enabled real-time monitoring of safety conditions during our projects, providing us with invaluable insights	QCSE5

Latent Component	Indicator Variable	Measurement Variable	Label
		to proactively address safety concerns and ensure the well-being of our workforce	
		BIM-enabled simulations have facilitated improved material selection within our organization, allowing us to make more informed choices that prioritize sustainability	QCSE6

Table A 20 Factor Loading and P-Value of the Impact of BIM on Construction Project Performance Construct

Hypothesised relationships (Path)	Unstandardised Coefficient (λ)	Standardised Coefficient (λ)	P-Value	R- Square	Significant at 5% Level
PEPO1 ← PEPO	1.000	0.928	0.00	0.861	Yes
PEPO2 ← PEPO	0.981	0.918	0.00	0.843	Yes
PEPO3 ← PEPO	0.998	0.874	0.00	0.764	Yes
PEPO4 ← PEPO	0.994	0.925	0.00	0.856	Yes
PEPO5 ← PEPO	0.993	0.895	0.00	0.802	Yes
PEPO6 ← PEPO	0.949	0.898	0.00	0.806	Yes
PEPO7 ← PEPO	0.992	0.934	0.00	0.873	Yes
PEPO8 ← PEPO	0.920	0.891	0.00	0.794	Yes
PEPO9 ← PEPO	0.967	0.914	0.00	0.835	Yes
PEPO10 ← PEPO	0.965	0.903	0.00	0.815	Yes
PEPO11 ← PEPO	0.840	0.782	0.00	0.611	Yes
QCSE1 ← QCSE	1.000	0.983	0.00	0.966	Yes
QCSE2 ← QCSE	0.945	0.937	0.00	0.879	Yes
QCSE3 ← QCSE	0.876	0.891	0.00	0.794	Yes
QCSE4 ← QCSE	0.865	0.879	0.00	0.773	Yes
QCSE5 ← QCSE	0.893	0.892	0.00	0.796	Yes
QCSE6 ← QCSE	0.858	0.858	0.00	0.736	Yes

Table A 21 Unidimensionality of the Strategies for Effective Adoption of BIM

Items	OCS	TMS	PRS	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Conducting thorough cost-benefit analyses for BIM adoption in projects as a way of demonstrating its	0.785			0.779	0.789	0.991	0.991

Items	OCS	TMS	PRS	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
value to stakeholders. Developing standardized BIM contract terms and conditions will facilitate smoother adoption.	0.768			0.839	0.849	0.991	
Demonstrating the long-term financial benefits of BIM will encourage adoption.	0.768			0.870	0.880	0.990	
Involving all stakeholders early in the BIM process is essential for effective adoption.	0.766			0.865	0.875	0.990	
Including BIM-specific clauses in construction contracts to address liabilities and responsibilities will streamline adoption.	0.762			0.897	0.907	0.990	
Establishing benchmarks and performance metrics for BIM projects will help organizations measure success and improve adoption strategies.	0.760			0.872	0.882	0.990	

Items	OCS	TMS	PRS	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Implementing collaborative procurement models will support BIM adoption by improving coordination among stakeholders.	0.758			0.885	0.895	0.990	
Ensuring legal frameworks are in place to handle intellectual property and data ownership issues related to BIM models.	0.753			0.883	0.893	0.990	
Adopting risk-sharing frameworks for BIM projects will encourage organizations to implement the technology.	0.753			0.873	0.883	0.990	
Encouraging contractual agreements that foster BIM collaboration between different project teams will drive adoption.	0.751			0.889	0.899	0.990	
Offering financial assistance or subsidies for small and medium enterprises (SMEs)	0.751			0.898	0.908	0.990	

Items	OCS	TMS	PRS	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
to adopt BIM will promote its widespread use. Conducting regular reviews of BIM project performance and sharing the results with stakeholders will promote continuous improvement.	0.745			0.909	0.919	0.990	
Organizing industry-wide forums, conferences, and seminars on BIM will help share knowledge and best practices for adoption.	0.713			0.892	0.902	0.990	
Encouraging open collaboration and data sharing among project participants is critical for effective BIM adoption.	0.698			0.879	0.889	0.990	
Upskilling the workforce through hands-on BIM experience and practical training is key to successful implementation.	0.659			0.911	0.921	0.990	

Items	OCS	TMS	PRS	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Investing in advanced technology infrastructure (hardware, software, and networking) is critical for successful BIM adoption.		0.752		0.894	0.904	0.990	
Fostering a culture of innovation within organizations is important for encouraging BIM adoption.		0.749		0.891	0.901	0.990	
Industry collaboration with academic institutions to provide BIM-focused education and training programs will improve BIM readiness.		0.712		0.869	0.879	0.990	
Ensuring interoperability between different BIM software platforms is essential for seamless		0.702		0.913	0.923	0.990	

Items	OCS	TMS	PRS	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
collaboration on projects.							
Implementing secure and efficient data-sharing platforms is crucial for BIM adoption.		0.687		0.880	0.890	0.990	
Promotion of cross-departmental collaboration within organizations is key to the success of BIM adoption.		0.659		0.918	0.928	0.990	
Establishing BIM certification programs for professionals will drive skill development and adoption in the industry.		0.629		0.866	0.876	0.990	
Allocation of sufficient resources by organizations towards BIM implementation is a critical		0.598		0.879	0.889	0.990	
Establishment of clear strategic vision and roadmap for BIM integration is essential for successful adoption.		0.590		0.905	0.915	0.990	
Senior management's		0.585		0.914	0.924	0.990	

Items	OCS	TMS	PRS	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
commitment to BIM adoption is key to ensuring a successful implementation strategy.							
Government support and incentives are crucial for effective BIM adoption			0.801	0.898	0.908	0.990	
Enforceable government regulations on BIM usage will encourage broader adoption across the construction industry.			0.737	0.897	0.907	0.990	
Establishing national BIM standards and guidelines is essential for ensuring consistency in BIM implementation.			0.715	0.896	0.906	0.990	
Government-mandated BIM requirements for public funded projects will drive BIM adoption in the construction industry.			0.678	0.894	0.904	0.990	

Table A 22 Final Conceptual Model Indicator Variables for the Strategies for Effective Adoption of BIM Construct

Latent Component	Indicator Variable	Measurement Variable	Label
Organizational and Collaborative Strategies (OCS)		Conducting thorough cost-benefit analyses for BIM adoption in projects as a way of demonstrating its value to stakeholders.	OCS1
		Developing standardized BIM contract terms and conditions will facilitate smoother adoption.	OCS2
		Demonstrating the long-term financial benefits of BIM will encourage adoption.	OCS3
		Involving all stakeholders early in the BIM process is essential for effective adoption.	OCS4
		Including BIM-specific clauses in construction contracts to address liabilities and responsibilities will streamline adoption.	OCS5
		Establishing benchmarks and performance metrics for BIM projects will help organizations measure success and improve adoption strategies.	OCS6
		Implementing collaborative procurement models will support BIM adoption by improving coordination among stakeholders.	OCS7
		Ensuring legal frameworks are in place to handle intellectual property and data ownership issues related to BIM models.	OCS8
		Adopting risk-sharing frameworks for BIM projects will encourage organizations to implement the technology.	OCS9
		Encouraging contractual agreements that foster BIM collaboration between different project teams will drive adoption.	OCS10
		Offering financial assistance or subsidies for small and medium enterprises (SMEs) to adopt BIM will promote its widespread use.	OCS11
		Conducting regular reviews of BIM project performance and sharing the results with stakeholders will promote continuous improvement.	OCS12

	Organizing industry-wide forums, conferences, and seminars on BIM will help share knowledge and best practices for adoption.	OCS13
	Encouraging open collaboration and data sharing among project participants is critical for effective BIM adoption.	OCS14
	Upskilling the workforce through hands-on BIM experience and practical training is key to successful implementation.	OCS15
Technological and Managerial Strategies (TMS)	Investing in advanced technology infrastructure (hardware, software, and networking) is critical for successful BIM adoption.	TMS1
	Fostering a culture of innovation within organizations is important for encouraging BIM adoption.	TMS2
	Industry collaboration with academic institutions to provide BIM-focused education and training programs will improve BIM readiness.	TMS3
	Ensuring interoperability between different BIM software platforms is essential for seamless collaboration on projects.	TMS4
	Implementing secure and efficient data-sharing platforms is crucial for BIM adoption.	TMS5
	Promotion of cross-departmental collaboration within organizations is key to the success of BIM adoption.	TMS6
	Establishing BIM certification programs for professionals will drive skill development and adoption in the industry.	TMS7
	Allocation of sufficient resources by organizations towards BIM implementation is a critical	TMS8
	Establishment of clear strategic vision and roadmap for BIM integration is essential for successful adoption.	TMS9
	Senior management's commitment to BIM adoption is key to ensuring a successful implementation strategy.	TMS10
Policy and Regulatory Strategies (PRS)	Government support and incentives are crucial for effective BIM adoption	PRS1
	Enforceable government regulations on BIM usage will encourage broader adoption across the construction industry.	PRS2

	Establishing national BIM standards and guidelines is essential for ensuring consistency in BIM implementation.	PRS3
	Government-mandated BIM requirements for public funded projects will drive BIM adoption in the construction industry.	PRS4

Table A 23 Factor Loading and P-Value of the Strategies for Effective Adoption of BIM Construct

Hypothesised relationships (Path)	Unstandardised Coefficient (λ)	Standardised Coefficient (λ)	P-Value	R- Square	Significant at 5% Level
OCS1 ← OCS	1.00	0.911	0.00	0.829	Yes
OCS2 ← OCS	1.044	0.904	0.00	0.818	Yes
OCS3 ← OCS	1.060	0.942	0.00	0.887	Yes
OCS4 ← OCS	0.973	0.919	0.00	0.845	Yes
OCS5 ← OCS	1.051	0.921	0.00	0.849	Yes
OCS6 ← OCS	1.017	0.920	0.00	0.847	Yes
OCS7 ← OCS	0.940	0.895	0.00	0.802	Yes
OCS8 ← OCS	1.069	0.927	0.00	0.860	Yes
OCS9← OCS	1.006	0.934	0.00	0.873	Yes
OCS10 ← OCS	0.994	0.934	0.00	0.872	Yes
OCS11 ← OCS	0.971	0.891	0.00	0.795	Yes
OCS12 ← OCS	1.033	0.915	0.00	0.836	Yes
OCS13 ← OCS	0.991	0.911	0.00	0.830	Yes
OCS14 ← OCS	0.961	0.937	0.00	0.817	Yes
OCS15 ←OCS	0.980	0.932	0.00	0.823	Yes
TMS1 ← TMS	1.000	0.915	0.00	0.879	Yes
TMS2 ← TMS	0.944	0.911	0.00	0.868	Yes
TMS3 ← TMS	0.956	0.941	0.00	0.837	Yes
TMS4 ← TMS	1.023	0.927	0.00	0.886	Yes
TMS5 ← TMS	0.953	0.900	0.00	0.859	Yes
TMS6 ← TMS	0.928	0.878	0.00	0.810	Yes
TMS7 ← TMS	0.881	0.903	0.00	0.771	Yes
TMS8 ← TMS	0.991	0.961	0.00	0.815	Yes
TMS9 ← TMS	0.983	0.907	0.00	0.795	Yes
TMS10 ← TMS	0.979	0.940	0.00	0.836	Yes
PRS1 ← PRS	1.000	0.913	0.00	0.741	Yes
PRS2 ← PRS	1.018	0.904	0.00	0.823	Yes
PRS3 ← PRS	1.062	0.907	0.00	0.884	Yes
PRS4 ← PRS	0.927	0.892	0.00	0.833	Yes

Appendix B: Survey Questionnaire

Questionnaire

Dear Participant,

We request your participation in a doctoral research survey titled ***Digital Paradigm in Construction: Assessing the Adoption Dynamics of Building Information Modeling in Ghana's Construction Industry.***

Recent studies have brought to light the ongoing transformation of Ghana's construction industry, with the increasing recognition of Building Information Modeling (BIM) as a potent digital collaborative tool for improving project efficiency, reducing costs, and enhancing overall project performance. Despite this recognition, the adoption of BIM in Ghana's construction industry is still in its nascent stage, and there is a pressing need to understand the dynamics influencing its adoption and implementation.

We respectfully invite you to participate in the above research project due to your identified role in Ghana's Architecture, Engineering, and Construction (AEC) industry and your familiarity and understanding of BIM. The questionnaire, designed to gather valuable insights, will require approximately 25-30 minutes. Please be assured that all information provided will be treated confidentially, and no firm, organization, or individual will be identified in any report or publication stemming from this research.

You may conveniently complete the questionnaire online at …provide link…. or using the attached hard copy.

Your thoughtful input based on your expertise and experiences as a construction professional will be instrumental in generating insights that can benefit industry practitioners and academics.

Your feedback and participation are greatly appreciated, and we thank you in advance for your valuable contribution to this study.

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PART I: - Demographic Profile

Please tick (×) as appropriate

Code			
1	Gender	Male	[ ]
		Female	[ ]
2	Age	18-25 years	[ ]
		26-35 years	[ ]
		36-45 years	[ ]
		46-55 years	[ ]
		Over 55 years	[ ]
3	Academic Qualification	Certificate	[ ]
		HND/Diploma	[ ]
		Bachelor's Degree	[ ]
		Master's Degree	[ ]
		PhD	[ ]
4	Role	Architect	[ ]
		Structural/ Civil Engineer	[ ]
		MEP Engineer	[ ]
		Quantity Surveyor	[ ]
		Construction/Project Manager	[ ]
		Other	
5	Years of Experience	1-5 years	[ ]
		6-10 years	[ ]
		11-15 years	[ ]
		16-20 years	[ ]
		21-25 years	[ ]
		More than 25 years	[ ]
6	Organization Type	Consulting	[ ]
		Construction	[ ]
		Development Authority	[ ]
7	Size of Organization	Micro: 1-5 employees	[ ]
		Small: 6-30 employees	[ ]
		Medium: 31-100 employees	[ ]
		Large: more than 100 employees	[ ]
8	Location of Organization	Ashanti Region	[ ]
		Brong Ahafo Region	[ ]
		Central Region	[ ]
		Eastern Region	[ ]
		Greater Accra Region	[ ]
		Northern Region	[ ]
		Upper East Region	[ ]
		Upper West Region	[ ]
		Volta Region	[ ]

		Western Region	[ ]
		Savannah Region	[ ]
		Bono East Region	[ ]
		Oti Region	[ ]
		Ahafo Region	[ ]
		Western North Region	[ ]
		North East Region	[ ]

PART II

BIM Adoption

Please indicate the extent to which you agree or disagree with each of the following statements regarding BIM adoption in your organization. Tick the appropriate box provided, where 1-Strongly Disagree, 2-Disagree, 3-Disagree Somewhat, 4-Neutral, 5-Agree Somewhat, 6-Agree, 7- Strongly Agree.

Code		**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	Our organization has seamlessly integrated BIM technologies into our routine project practices.							
2	BIM technologies are a fundamental tool guiding our project management and decision-making.							
3	Our organization is at BIM Level 0 (2D CAD drawings and paper-based communication).							
4	Our organization is at BIM Level 1 (combining 2D and 3D CAD models).							
5	Our organization is at BIM Level 2 (collaborative federated BIM models).							
6	Our organization is at BIM Level 3 (full integration with a single shared model among project participants).							

PART III

BIM Awareness and Knowledge

This section is designed to assess your level of awareness and knowledge of BIM. Your responses will help identify how familiar Ghana's construction industry is with BIM practices and how widely BIM tools are adopted.

Please indicate the extent to which you agree or disagree with each of the statements by ticking the appropriate box provided, where 1-Strongly Disagree, 2-Disagree, 3-Disagree Somewhat, 4- Neutral, 5-Agree Somewhat, 6-Agree, 7- Strongly Agree.

Code	**BIM Concept**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	I am aware of the concept of BIM.							
2	I am aware that BIM is more than 3D modelling; it involves managing project information.							
3	I am aware that BIM is all about real-time collaboration throughout a project's lifecycle.							
4	I am aware of how BIM significantly changes the traditional workflow in the construction industry.							
5	I am aware of the difference between BIM and traditional 3D CAD systems.							
6	I am aware of BIM maturity levels and their implications for project collaboration.							
7	I am aware that BIM represents the future of managing project information in construction.							
8	I hear more about BIM in industry discussions now than in the past.							
	BIM Benefits	**1**	**2**	**3**	**4**	**5**	**6**	**7**
9	I am aware that BIM reduces errors and the need for rework in construction projects.							
10	I am aware that BIM enhances communication and coordination between project stakeholders.							
11	I am aware that BIM helps improve the overall visualization of a construction project.							
12	I am aware that BIM improves the quality of construction outcomes.							
13	I am aware that BIM helps in reducing project costs.							
14	I am aware that BIM allows faster and more efficient decision-making in project execution.							
15	I am aware that BIM helps detect clashes in designs.							
	Standards and Roadmaps	**1**	**2**	**3**	**4**	**5**	**6**	**7**
16	I am familiar with international BIM standards.							
17	I am aware of BIM roadmaps for implementation in the construction industry.							
18	I am aware that following BIM roadmaps is important for successful implementation.							
19	I am aware that BIM can be applied during the design phase for 3D visualizations and simulations.							

20	I am aware that BIM is used during the construction phase to monitor progress and detect clashes.							
21	I am aware that BIM can be used for facility management after project completion.							
BIM Knowledge								
	Fundamentals of BIM	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	I am proficient in using BIM software.							
2	I can manipulate 3D models using BIM software.							
3	I can run clash detection using BIM software.							
4	I can generate automatic schedules and quantities using BIM tools.							
5	I know how to export/import BIM data using various file formats.							
	BIM Implementation in Projects	**1**	**2**	**3**	**4**	**5**	**6**	**7**
6	I understand the steps required to implement BIM on a project.							
7	I am familiar with developing and following a BIM Execution Plan (BEP).							
8	I know how to work collaboratively with other disciplines using a BIM model.							
	Training and Knowledge Acquisition in BIM	**1**	**2**	**3**	**4**	**5**	**6**	**7**
9	I have received formal training in BIM software and processes.							
10	I have gained practical experience by working on BIM projects.							
11	My organization provides opportunities for continuous BIM training and development.							
	Advanced BIM Knowledge	**1**	**2**	**3**	**4**	**5**	**6**	**7**
12	I understand how 4D BIM (scheduling) and 5D BIM (estimating) are applied in construction projects.							
13	I am familiar with the integration of BIM with emerging technologies, such as virtual reality (VR) and augmented reality (AR).							
14	I know the concept of Digital Twins and its relationship with BIM for real-time data management and simulation.							

PART IV

Organizational and Technological Readiness of Ghana's Construction Industry Towards BIM Adoption

Please indicate the extent to which you agree or disagree with each of the following statements regarding Ghana's construction industry's organizational and technological readiness towards BIM adoption. Indicate on a scale of 1-7 by ticking the appropriate box provided, where 1-Strongly Disagree, 2-Disagree, 3-Disagree Somewhat, 4- Neutral, 5-Agree Somewhat, 6-Agree, 7- Strongly Agree.

Code	**Management Attitude**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	Our organization's senior management is committed to adopting new technologies like BIM.							
2	Our management believes that BIM will lead to long-term benefits despite the initial challenges of implementation.							
3	Our management fosters a culture of innovation that supports the adoption of BIM across all levels of the organization.							
	Established BIM Implementation Strategy	**1**	**2**	**3**	**4**	**5**	**6**	**7**
4	Our organization has a clearly defined and documented strategy for the implementation of BIM.							
5	The implementation of BIM aligns with our organization's long-term goals.							
6	A systematic approach is in place to monitor and evaluate the progress of BIM implementation within our organization.							
	Integration of BIM in Project Workflows	**1**	**2**	**3**	**4**	**5**	**6**	**7**
7	BIM technologies are integrated into only the design stage of our project workflows.							
8	BIM technologies are integrated into both the design and construction stages of our project workflow.							
9	BIM technologies are integrated into every stage of our project workflow, from design to construction and beyond.							
10	Our project management processes are adapted to accommodate BIM.							

11	The use of BIM tools is an integral part of our project planning.							
	Collaborative Culture	**1**	**2**	**3**	**4**	**5**	**6**	**7**
12	Our organization encourages cross-disciplinary collaboration among different departments for BIM implementation.							
13	Our workforce is capable of collaborating effectively across disciplines (e.g., architects, engineers, contractors) in BIM projects.							
14	Our workforce understands how to use BIM for better coordination between different project teams.							
15	Our workforce is skilled at using BIM to facilitate communication and data sharing between various stakeholders in a project.							
	Availability of Skilled Workforce	**1**	**2**	**3**	**4**	**5**	**6**	**7**
16	Our organization has enough staff with the required skills to implement BIM.							
17	Our organization employs professionals with specialized skills and expertise in utilizing BIM.							
	BIM Training and Competency Development	**1**	**2**	**3**	**4**	**5**	**6**	**7**
18	A significant portion of our workforce has received formal BIM training or certifications.							
19	Our organization offers employees regular in-house training sessions on BIM.							
20	Our organization provides access to external BIM training programs to enhance the BIM-related skills of our workforce.							
21	BIM training in our organization is mostly self-led by employees.							
22	Employees are encouraged and supported to pursue professional BIM certification programs.							
23	The effectiveness of our BIM training programs is measured through feedback and improved application of learned skills.							
	Technological Infrastructure	**1**	**2**	**3**	**4**	**5**	**6**	**7**
24	Our organization has invested in the latest BIM software to support project workflows.							
25	We regularly invest in upgrading our technological infrastructure to support the seamless integration of BIM-related technologies.							

26	Our organization has a reliable IT infrastructure capable of handling the demands of BIM software efficiently.							
27	We have established systems for secure and efficient data sharing and collaboration.							
28	Our organization has a dedicated IT or technical support team.							

PART V

Key Drivers and Barriers Influencing the Adoption and Implementation of BIM in Ghana's Construction Industry

A.

Please indicate the extent to which you agree or disagree with each of the following statements regarding the factors that may likely be driving the adoption of BIM in your organization. Indicate on a scale of 1-7 in the box provided, where 1-Strongly Disagree, 2-Disagree, 3-Disagree Somewhat, 4- Neutral, 5-Agree Somewhat, 6-Agree, 7- Strongly Agree.

Code	**BIM Drivers**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	Regulatory policies have played a significant role in encouraging BIM adoption within our organization.							
2	Government incentives have played a significant role in encouraging BIM adoption within our organization.							
3	BIM's potential to reduce project costs motivates us to adopt it.							
4	The efficiency gains associated with BIM motivate us to adopt it.							
5	The potential for long-term return on investment (ROI) from BIM adoption is a key driver.							
6	The demand from clients for BIM-based project delivery motivates us to adopt BIM.							
7	BIM adoption provides a competitive edge in winning new construction projects.							
8	The growing industry trend toward digital transformation has prompted our organization to embrace BIM as a competitive advantage.							

Code	**BIM Drivers**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
9	BIM's ability to streamline workflows and improve collaboration is a key driver for adoption.							
10	BIM's ability to improve collaboration between different project stakeholders drives our organization to adopt it.							
11	The capability of BIM to manage project data more efficiently is a significant factor in its adoption.							
12	BIM's ability to reduce project risks by identifying potential issues early in the design phase drives adoption.							
13	The overall improvement in construction project quality due to BIM is a key driver for adoption.							
14	The increasing availability of BIM training programs and certification for our workforce motivates BIM adoption.							
15	BIM's capability to reduce errors has motivated our organization to integrate these technologies.							
16	BIM's capability to improve decision-making has motivated our organization to integrate these technologies.							

B.

Please indicate the extent to which you agree or disagree with each of the following statements regarding the factors that may likely be hindering the adoption of BIM in your organization. Indicate on a scale of 1-7 in the box provided, where 1-Strongly Disagree, 2-Disagree, 3-Disagree Somewhat, 4- Neutral, 5-Agree Somewhat, 6-Agree, 7- Strongly Agree.

Code	**BIM Barriers**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	Limited awareness among organizational leadership about the potential benefits of BIM.							
2	Lack of senior management buy-in							
3	Lack of awareness of BIM by industry stakeholders							
4	Lack of demand and interest from the clients in the application of BIM in their projects.							

Code	BIM Barriers	1	2	3	4	5	6	7
5	Lack of a government mandate for BIM implementation.							
6	Lack of government regulations to support the implementation of BIM							
7	Lack of IT infrastructure							
8	High cost of Data to operate cloud-based BIM							
9	The initial cost of the technology required for BIM implementation							
10	The industry's cultural resistance to change							
11	Lack of training courses for industry professionals							
12	Cost of BIM education and training							
13	Lack of skilled professionals with BIM expertise.							
14	Lack of case studies that have implemented BIM and realized a positive return on investment (ROI)							
15	Lack of project funding to support BIM							
16	The reluctance of other project parties to share information							
17	Non-adoption of BIM by other industry professionals							
18	Data interoperability challenges between various BIM software.							
19	Unavailability of BIM risk insurance							
20	Lack of industry BIM standards and guidelines for implementation							
21	Data security issues							
22	Lack of standard contract to deal with responsibility/risk assignment and BIM ownership.							
23	The steep learning curve to develop BIM expertise							
24	Low computer skills among construction professionals.							

Part VI

Impact of BIM on Construction Project Performance

Please indicate the extent to which you agree or disagree with each of the following statements regarding the impact of BIM adoption on construction project performance in Ghana. Indicate on a scale of 1-7 by ticking the appropriate box

provided, where 1-Strongly Disagree, 2-Disagree, 3-Disagree Somewhat, 4-Neutral, 5-Agree Somewhat, 6-Agree, 7- Strongly Agree.

Code	**Impact of BIM**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	BIM-enabled simulations and visualizations have positively impacted stakeholder communication, leading to smoother project execution.							
2	Our organization has observed a significant reduction in rework since implementing BIM.							
3	BIM implementation has led to substantial cost savings for our organization by streamlining work processes							
4	Our organization has observed improved budget adherence across our projects with the integration of BIM.							
5	The integration of BIM technologies has contributed to our organization's timely completion of projects.							
6	BIM has played a crucial role in optimizing construction sequencing and planning within our organization.							
7	We have witnessed a significant improvement in tracking change orders throughout our project with the implementation of BIM.							
8	Our organization has witnessed a marked reduction in errors since integrating BIM into our processes.							
9	BIM has significantly improved our quality control measures, allowing us to detect and address potential issues early in the project lifecycle,							
10	BIM has enabled real-time monitoring of safety conditions during our projects, providing us with invaluable insights to proactively address safety concerns and ensure the well-being of our workforce.							
11	Our organization has witnessed tangible improvements in the energy efficiency of our projects through the integration of BIM.							
12	BIM-enabled simulations have facilitated improved material selection within our organization, allowing us to make more informed choices that prioritize sustainability.							

Part VII

Strategies for effective BIM adoption.

Please indicate the extent to which you agree or disagree with each of the following statements regarding the strategies for effective BIM adoption in Ghana. Indicate on a scale of 1-7 by ticking the appropriate box provided, where 1-Strongly Disagree, 2-Disagree, 3-Disagree Somewhat, 4- Neutral, 5-Agree Somewhat, 6-Agree, 7- Strongly Agree.

Code		**1**	**2**	**3**	**4**	**5**	**6**	**7**
	Government and Policy-Driven Strategies							
1	Government support and incentives are crucial for effective BIM adoption.							
2	Enforceable government regulations on BIM usage will encourage broader adoption across the construction industry.							
3	Establishing national BIM standards and guidelines is essential for ensuring consistency in BIM implementation.							
4	Government-mandated BIM requirements for publicly funded projects will drive BIM adoption in the construction industry.							
	Organizational Strategies	**1**	**2**	**3**	**4**	**5**	**6**	**7**
5	Senior management's commitment to BIM adoption is key to ensuring a successful implementation strategy.							
6	The establishment of a clear strategic vision and roadmap for BIM integration is essential for successful adoption.							
7	Allocation of sufficient resources by organizations towards BIM implementation is a critical							
8	Fostering a culture of innovation within organizations is important for encouraging BIM adoption.							
9	The promotion of cross-departmental collaboration within organizations is key to the success of BIM adoption.							
	Technology and Infrastructure Strategies	**1**	**2**	**3**	**4**	**5**	**6**	**7**

Code		1	2	3	4	5	6	7
10	Investing in advanced technology infrastructure (hardware, software, and networking) is critical for successful BIM adoption.							
11	Implementing secure and efficient data-sharing platforms is crucial for BIM adoption.							
12	Ensuring interoperability between different BIM software platforms is essential for seamless collaboration on projects.							
	Capacity Building and Training Strategies	**1**	**2**	**3**	**4**	**5**	**6**	**7**
13	Industry collaboration with academic institutions to provide BIM-focused education and training programs will improve BIM readiness.							
14	Establishing BIM certification programs for professionals will drive skill development and adoption in the industry.							
15	Upskilling the workforce through hands-on BIM experience and practical training is key to successful implementation.							
	Collaboration and Stakeholder Engagement							
16	Involving all stakeholders early in the BIM process is essential for effective adoption.							
17	Encouraging open collaboration and data sharing among project participants is critical for effective BIM adoption.							
19	Implementing collaborative procurement models will support BIM adoption by improving coordination among stakeholders.							
20	Encouraging contractual agreements that foster BIM collaboration between different project teams will drive adoption.							
	Cost and Financial Strategies	**1**	**2**	**3**	**4**	**5**	**6**	**7**
21	Conducting thorough cost-benefit analyses for BIM adoption in projects as a way of demonstrating its value to stakeholders.							
22	Demonstrating the long-term financial benefits of BIM will encourage adoption.							
23	Offering financial assistance or subsidies for small and medium enterprises (SMEs) to adopt BIM will promote its widespread use.							
	Legal and Contractual Strategies	**1**	**2**	**3**	**4**	**5**	**6**	**7**

Code		**1**	**2**	**3**	**4**	**5**	**6**	**7**
24	Developing standardized BIM contract terms and conditions will facilitate smoother adoption.							
25	Ensuring legal frameworks are in place to handle intellectual property and data ownership issues related to BIM models.							
26	Adopting risk-sharing frameworks for BIM projects will encourage organizations to implement the technology.							
27	Including BIM-specific clauses in construction contracts to address liabilities and responsibilities will streamline adoption.							
	Market and Industry-Driven Strategies	**1**	**2**	**3**	**4**	**5**	**6**	**7**
28	Organizing industry-wide forums, conferences, and seminars on BIM will help share knowledge and best practices for adoption.							
29	Establishing benchmarks and performance metrics for BIM projects will help organizations measure success and improve adoption strategies.							
30	Conducting regular reviews of BIM project performance and sharing the results with stakeholders will promote continuous improvement.							

Appendix C: Interview Guide

Interview Guide

Interview Guide for Industry Experts and Consultants

Demographic Information

1. Name: ……..
2. Organization:.……..……..
3. Position/Title:…….
4. Years of Experience in the Industry:….…….
5. Specialization/Area of Expertise:……
6. How did you get the exposure to BIM ……

(Formal education, professional training and certification, workshops and seminars, on-the-job training, self-study or online courses).

Main Issues

Awareness and Knowledge of BIM

7. Based on your experience, how would you describe the current level of awareness and understanding of BIM among construction professionals?
8. In your opinion, which specific professionals within the industry typically demonstrate awareness of BIM, and what factors contribute to their familiarity and readiness to embrace this technology?
9. How do you think the level of awareness and knowledge of BIM among construction professionals affects the overall BIM adoption effort in Ghana's construction industry?

Readiness of Ghana's Construction Industry towards BIM Adoption.

10. How ready are AEC firms in Ghana's construction industry for effective BIM adoption?
11. In your experience, what organizational changes or adjustments are necessary for AEC firms to improve their BIM adoption?
12. What kind of BIM training or professional development programs are available and used in your organization?
13. In your opinion, which specific BIM tools and software solutions are commonly used by industry professionals?

- Are the BIM tools readily available and affordable?

14. What are your thoughts on the government providing support for adopting BIM in terms of software, technology, and infrastructure?

Drivers and Barriers to BIM Adoption in Ghana's Construction Industry.

15. From your perspective, what are the main factors that drive organizations to adopt BIM on their projects?

16. What do you perceive as the main obstacles hindering the widespread adoption of BIM in the industry?

Impact of BIM Adoption on Construction Project Performance in Ghana.

17. In your experience, how has the adoption of BIM affected the overall success of construction projects?

    - What additional services were you able to offer clients due to BIM adoption?

18. At what specific stage or phase of a project do you believe BIM implementation provides the greatest value and why do you think so?

19. What unexpected difficulties have you encountered in assessing the true impact of BIM on project performance?

Toward Effective BIM Adoption in the Construction Industry in Ghana.

20. Could you please provide details on any guidelines, protocols, or standards that exist for adopting BIM in Ghana?

21. Based on your experience, what strategies do you believe would be most effective in promoting and facilitating the successful adoption of BIM across various sectors of Ghana's construction industry?

22. In your opinion, which stakeholder(s) should take the lead in championing the widespread BIM implementation and why do you believe they are best suited for this role?

23. What future trends do you foresee in the adoption and implementation of BIM in Ghana's construction industry?

Interview Guide for Government Officials

Demographic Questions:

1. Name: ……
2. Title/Position:…….
3. Ministry/Institution/Department/:……..
4. Years of Experience in Public Service:……..

Interview Questions:

Assessing Awareness and Knowledge of BIM

5. How would you describe the current level of awareness and understanding of BIM within government agencies and among policymakers?
6. Have there been any initiatives or efforts to promote BIM awareness and education in Ghana's construction industry? If yes, please describe.

Organizational and Technological Readiness

7. How would you describe the readiness of AEC firms in Ghana to adopt BIM in terms of their organizational capabilities?

Key Drivers and Barriers to BIM Adoption

8. From your perspective as a government official, what key factors drive the adoption of BIM in Ghana's construction industry?
9. What are the primary challenges hindering the widespread adoption of BIM?
10. What specific government policies exist to support the industry's BIM adoption effort in terms of software, technology, and infrastructure?

Impact of BIM Adoption on Project Performance

11. Based on your experience or observation, what impact has BIM adoption had on construction project performance in Ghana? If any?

Strategies for Effective Adoption

12. In your opinion, how could government collaborate with the private sector and academic institutions to promote effective adoption of BIM in Ghana's construction industry?
13. Could you share any government policies, regulations, or initiatives in place or being considered to promote the widespread adoption of BIM in Ghana's construction industry?
14. From your perspective, what potential long-term benefits could widespread BIM adoption bring to the construction industry and the nation?

Interview Guide for Clients

Demographic Questions:

1. Name:…….……..
2. Organization/Company:……..……..
3. Position/Title:……..……..
4. Type of Projects typically Engaged in (e.g., Residential, Commercial, Infrastructure, etc.) ……..…….……
5. Years of Experience in the Construction Industry: ..…….……..

Main Issues:

Awareness and knowledge of BIM

1. How familiar are you with BIM and its application in construction projects?

Key Drivers and Barriers to BIM Adoption

2. From your perspective as a client, what do you believe are the benefits of requiring the use of BIM on the construction projects you're involved in?
3. Have you encountered any challenges that make integrating BIM into your construction project delivery difficult?
4. How do you think clients/developers can influence the adoption of BIM within the construction industry?

Impact of BIM adoption on Construction project performance

5. In your experience, how has the adoption of BIM impacted the performance of your construction projects?
6. What role do you believe the government should play in facilitating and supporting BIM adoption?