RUDN Journal of Public Administration
ISSN 2312-8313 (Print), ISSN 2411-1228 (Online)
Вестник РУДН. Серия:
ГОСУДАРСТВЕННОЕ И МУНИЦИПАЛЬНОЕ УПРАВЛЕНИЕ
2025 Том 12 No 4 509–519
http://journals.rudn.ru/publicadministrationy

DOI: 10.22363/2312-8313-2025-12-4-509-519
EDN: LKGGTV

Research article / Научная статья

Digital twin and BIM adoption in construction project management: a quantitative expert-based study

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Abstract. This study investigates the role of Digital Twin (DT) services in facilitating the adoption of Building Information Modeling (BIM) in construction project management. Despite growing interest in digital transformation within the Architecture, Engineering, and Construction (AEC) industry, empirical evidence on how DT influences BIM implementation remains limited. To address this gap, a structured questionnaire was developed through an extensive literature review and distributed to 53 professionals actively engaged in BIM and DT applications, including contractors, consultants, and academics. The collected data were analyzed using SPSS with reliability tests (Cronbach's Alpha), Pearson correlation, independent-samples t-tests, and one-way ANOVA with post-hoc analysis. The results revealed strong internal consistency of the survey instrument (Cronbach's Alpha = 0.944), confirming the robustness of the measurement scale. Correlation analysis showed significant positive associations between DT service factors and BIM adoption ($p < 0.01$). Group comparisons demonstrated that perceptions of DT's contribution to BIM adoption varied across organizational roles, with notable differences between contractors, consultants, and research institutions ($p < 0.05$). These findings highlight the synergistic relationship between DT and BIM, suggesting that integrating DT services can enhance BIM utilization and overall project performance. The study contributes to academic knowledge and professional practice by providing empirical evidence of DT's enabling role in digital transformation. Practical implications include guiding policymakers, project managers, and technology providers in making informed decisions regarding DT-enabled BIM adoption. Although limited by its sample size and geographic scope, this research lays the groundwork for future studies employing larger international datasets and advanced statistical modeling. The results confirm the critical importance of DT services in accelerating successful BIM implementation across the construction sector.

Keywords: virtual replica, information modeling systems, project delivery in construction, innovation diffusion, data-driven assessment, digital shift in AEC

Contribution. All the authors participated in the development of the concept of this review, data collection, processing and analysis, drafted the manuscript, and formulated the conclusions.

Conflicts of interest. The authors declare no conflicts of interest.

Article history:
The article was submitted on 28.06.2025. The article was accepted on 26.08.2025.

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For citation:
Nguyen NM, Nguyen LV, Vu KV, Pham NT. Digital twin and BIM adoption in construction project management: a quantitative expert-based study. *RUDN Journal of Public Administration.* 2025;12(4):509–519. https://doi.org/10.22363/2312-8313-2025-12-4-509-519 EDN: LKGGTV

Цифровой двойник и внедрение BIM в управлении строительными проектами: количественное исследование, основанное на мнении экспертов

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Аннотация. Рассмотрена роль сервисов цифрового двойника (DT) в содействии внедрению информационного моделирования зданий (BIM) в управлении строительными проектами. Несмотря на растущий интерес к цифровой трансформации в отрасли архитектуры, строительства и эксплуатации (AEC), эмпирические данные о том, как DT влияет на использование BIM, остаются ограниченными. Для восполнения этого пробела на основе обширного анализа литературы разработана структурированная анкета, распространенная среди 53 специалистов, активно работающих с BIM и DT, включая подрядчиков, консультантов и представителей академической среды. Собранные данные проанализировали с помощью SPSS, включая тест надежности (альфа Кронбаха), корреляцию Пирсона, t-тест для независимых выборок и однофакторный дисперсионный анализ (ANOVA) с пост-хок проверкой. Результаты показали высокую внутреннюю согласованность опросника (альфа Кронбаха = 0,944), что подтверждает надежность шкалы измерения. Корреляционный анализ выявил значительные положительные связи между факторами сервисов DT и внедрением BIM ($p < 0{,}01$). Сравнительный анализ показал, что восприятие вклада DT в использование BIM различается в зависимости от организационной роли, при этом существенные различия наблюдаются между подрядчиками, консультантами и научно-исследовательскими учреждениями ($p < 0{,}05$). Эти результаты подчеркивают синергетическую взаимосвязь между DT и BIM, указывая на то, что интеграция сервисов DT может повысить эффективность применения BIM и результативность проектов в целом. Исследование вносит вклад как в академическую литературу, так и в профессиональную практику, предоставляя эмпирические доказательства роли DT в цифровой трансформации. Практическая значимость заключается в поддержке решений политиков, руководителей проектов и поставщиков технологий относительно внедрения BIM, поддерживаемого DT. Несмотря на ограниченность выборки и географии, исследование создает основу для будущих работ с использованием международных данных и расширенного статистического моделирования. Полученные результаты подтверждают критическую важность сервисов DT для успешного внедрения BIM в строительной отрасли.

Ключевые слова: виртуальная модель, моделирование объектов, координация проектов в строительстве, освоение инноваций, эмпирическая оценка, эволюция отрасли AEC

Вклад авторов. Все авторы участвовали в разработке концепции исследования, сборе, обработке и анализе данных, написании текста рукописи, формулировке выводов.

Заявление о конфликте интересов. Авторы заявляют об отсутствии конфликта интересов.

История статьи:
Поступила в редакцию 28.06.2025; принята к публикации 26.08.2025.

Для цитирования:
Nguyen N.M., Nguyen L.V., Vu K.V., Pham N.T. Digital twin and BIM adoption in construction project management: a quantitative expert-based study // Вестник Российского университета дружбы народов. Серия: Государственное и муниципальное управление. 2025. Т. 12. № 4. С. 509–519. https://doi.org/10.22363/2312-8313-2025-12-4-509-519 EDN: LKGGTV

Introduction

Over the past decade, the construction industry has undergone a significant digital transformation, with Building Information Modeling (BIM) emerging as a key methodology to enhance project coordination, cost estimation, scheduling, and lifecycle decision-making [1; 2]. Despite these recognized benefits, BIM adoption faces substantial challenges, including limited interoperability, high implementation costs, resistance to organizational change, and shortages of skilled personnel — especially in developing regions [3; 4].

Simultaneously, the emergence of Digital Twin (DT) technologies has offered opportunities for real-time connectivity between physical assets and their digital counterparts, enabling advanced simulation, predictive analytics, and operational control [5; 6]. Although previous reviews have outlined the enabling technologies and conceptual synergies between DT and BIM [7; 8], empirical studies exploring how DT implementation affects BIM uptake in real construction practice remain limited.

Existing literature is dominated by conceptual models and theoretical discussions, with a notable lack of quantitative validation from practitioners' perspectives [9; 10]. This gap is particularly relevant as organizations increasingly invest in digital transformation initiatives without clear evidence on return or implementation effectiveness.

To address this gap, the current study investigates the perceptions of industry professionals regarding how DT services influence BIM adoption in construction project management. The study's objectives are to:

- Quantitatively assess the perceived impact of DT services on BIM adoption.
- Examine the correlations between specific DT capabilities and BIM utilization.
- Identify organizational factors affecting perceptions of DT–BIM integration.
- Provide empirical evidence to support strategic digital technology investments.

Purpose of the study is to investigate how DT services influence the adoption of BIM in construction project management. By capturing the perspectives of industry professionals, this research aims to provide empirical evidence on the relationship between specific DT capabilities and the extent of BIM utilization. Furthermore, the study seeks to identify how different organizational roles, such as contractors, consultants, and researchers, perceive the value of DT-enabled tools in enhancing BIM implementation. Ultimately, the findings are intended to support strategic decision-making among stakeholders in the Architecture, Engineering, and Construction (AEC) sector regarding digital transformation investments.

Materials and methods

This study employs a quantitative survey-based methodology to evaluate industry experts' perceptions of how DT services influence the adoption of BIM in construction project management. The research design comprised the following stages:

Survey instrument design: The questionnaire was developed based on a thorough review of existing BIM–DT integration literature, using validated constructs from studies such as Deng et al. [9] and Omrany et al. [10].

Sample and data collection: A purposive sampling strategy targeted 53 professionals engaged in BIM and/or DT implementation, including contractors, consultants, and academic/research institutes. Invitations were sent electronically, and responses were collected online between March and May, 2025.

Reliability and validity assessment: Cronbach's Alpha was computed to assess the internal consistency of each construct. An alpha coefficient surpassing 0.90 confirmed high reliability, consistent with established quantitative research standards [11].

Descriptive and inferential statistical analysis: Descriptive statistics (mean, standard deviation) characterized respondents' demographic and organizational profiles. Pearson correlation analysis examined relationships between DT-related variables and BIM adoption levels.

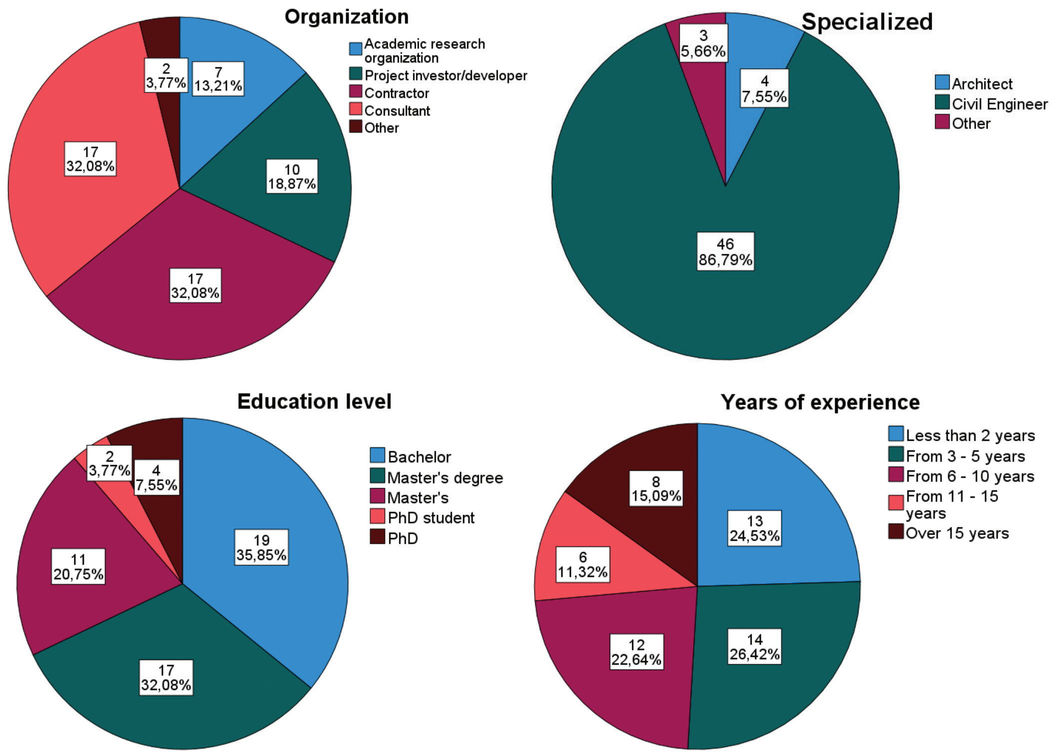
Data normality and diagnostic tests: Normality of responses was verified using skewness and kurtosis metrics. Homogeneity of variances was checked via Levene's test. These tests ensured the validity of parametric inferential procedures.

This methodology integrates best practices from empirical research in AEC digital technology adoption [12], enabling robust interpretation of data that bridges theory and practice. By leveraging statistical rigor, this study aims to provide defensible evidence on the impact of DT services on BIM uptake within the construction industry, operationalized through practitioners' perceptions.

Results

A total of 53 industry professionals participated in the survey. The majority were civil engineers, followed by architects and other related specialists. The demographic breakdown of the respondents is summarized in Figure, which presents key characteristics such as professional roles, specialization areas, education levels, and years of experience.

The internal consistency of the survey items measuring DT services' influence on BIM adoption was tested using Cronbach's Alpha. The result yielded a value of 0.944, exceeding the commonly accepted threshold of 0.70 for reliability, and demonstrating strong internal consistency among the items. Table 1 presents the item-total statistics, including each item's correlation with the overall scale and the effect on Cronbach's Alpha if the item were deleted, thereby confirming the robustness of the measurement construct.



Demographic characteristics of survey respondents

Source: made by L.M. Nguyen, K.V. Vu with the use of MS Word.

Table 1

Cronbach's Alpha and item-total statistics assess the internal consistency of survey items related to the DT services' influence on BIM adoption

Item-Total Statistics					
N	**Scale Mean if Item Deleted**	**Scale Variance if Item Deleted**	**Corrected Item-Total Correlation**	**Squared Multiple Correlation**	**Cronbach›s Alpha if Item Deleted**
Y1	37.00	45.269	0.769	0.778	0.938
Y2	37.04	44.691	0.789	0.775	0.938
Y3	36.85	44.631	0.773	0.781	0.938
Y4	37.11	43.141	0.806	0.711	0.937
Y5	37.19	45.156	0.741	0.748	0.940
Y6	37.02	44.865	0.777	0.748	0.938
Y7	36.96	45.691	0.768	0.799	0.939
Y8	36.98	45.057	0.747	0.820	0.939
Y9	37.19	46.964	0.633	0.660	0.943
Y10	37.13	44.617	0.800	0.846	0.937
Y11	37.08	45.994	0.700	0.667	0.941
					0.944

Source: developed by L.M. Nguyen, L.V. Nguyen.

Table 2

Results of normality testing for survey items, showing means, standard deviations, skewness, and kurtosis values to assess the distributional characteristics of the data

Descriptive Statistics									
N	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Y1	53	2	5	3.75	0.806	0.025	0.327	−0.667	0.644
Y2	53	2	5	3.72	0.841	−0.020	0.327	−0.661	0.644
Y3	53	2	5	3.91	0.861	−0.378	0.327	−0.492	0.644
Y4	53	1	5	3.64	0.963	−0.420	0.327	−0.112	0.644
Y5	53	1	5	3.57	0.844	−0.215	0.327	0.569	0.644
Y6	53	1	5	3.74	0.836	−0.488	0.327	0.959	0.644
Y7	53	2	5	3.79	0.769	−0.150	0.327	−0.327	0.644
Y8	53	2	5	3.77	0.847	−0.331	0.327	−0.356	0.644
Y9	53	2	5	3.57	0.772	0.421	0.327	−0.456	0.644
Y10	53	2	5	3.62	0.837	0.004	0.327	−0.548	0.644
Y11	53	2	5	3.68	0.803	−0.037	0.327	−0.459	0.644
Valid N (listwise)	53								

Source: developed by L.M. Nguyen, L.V. Nguyen.

Pearson's correlation test revealed substantial and statistically significant positive relationships ($p < 0.01$) among the DT-related variables (Y1–Y11). Correlation coefficients ranged from 0.342 to 0.799, suggesting a consistent perception of DT services' positive contribution to BIM adoption, as reflected in the correlation matrix presented in Table 3.

Independent-samples t-tests comparing respondents from organizations with and without BIM adoption showed no statistically significant differences across most items ($p > 0.05$). At the same time, one-way ANOVA was performed to assess variations across different organizational roles. Descriptive group statistics for the BIM adoption comparison are provided in Table 4, with detailed t-test results in Table 5. The outcomes of the ANOVA, highlighting differences in perceptions across organizational roles, are summarized in Table 6.

Table 3

The Pearson correlation matrix shows statistically significant relationships concerning BIM adoption among DT-related variables (Y1–Y11)

Correlations												
N	**Corellation**	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**	**Y9**	**Y10**	**Y11**
Y1	Correlation	1	0.747	0.714	0.653	0.575	0.587	0.537	0.593	0.505	0.686	0.559
Y2	Correlation	0.747	1	0.653	0.609	0.583	0.685	0.711	0.665	0.488	0.610	0.575
Y3	Correlation	0.714	0.653	1	0.724	0.605	0.633	0.580	0.683	0.342	0.617	0.623
Y4	Correlation	0.653	0.609	0.724	1	0.728	0.645	0.599	0.630	0.537	0.664	0.644
Y5	Correlation	0.575	0.583	0.605	0.728	1	0.680	0.511	0.452	0.620	0.608	0.585
Y6	Correlation	0.587	0.685	0.633	0.645	0.680	1	0.751	0.512	0.594	0.542	0.616
Y7	Correlation	0.537	0.711	0.580	0.599	0.511	0.751	1	0.695	0.655	0.653	0.482
Y8	Correlation	0.593	0.665	0.683	0.630	0.452	0.512	0.695	1	0.494	0.799	0.485
Y9	Correlation	0.505	0.488	0.342	0.537	0.620	0.594	0.655	0.494	1	0.545	0.391
Y10	Correlation	0.686	0.610	0.617	0.664	0.608	0.542	0.653	0.799	0.545	1	0.674
Y11	Correlation	0.559	0.575	0.623	0.644	0.585	0.616	0.482	0.485	0.391	0.674	1

Source: developed by L.M. Nguyen, L.V. Nguyen.

Table 4

Group statistics comparing mean scores of DT-related items (Y1–Y11) between respondents from companies implementing BIM and those not implementing BIM

Group Statistics					
N	**Is your company implementing BIM?**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Y1	Yes	17	3.76	0.970	0.235
	No	36	3.75	0.732	0.122
Y2	Yes	17	3.71	0.849	0.206
	No	36	3.72	0.849	0.141
Y3	Yes	17	4.06	0.899	0.218
	No	36	3.83	0.845	0.141
Y4	Yes	17	3.53	1.231	0.298
	No	36	3.69	0.822	0.137
Y5	Yes	17	3.65	0.702	0.170
	No	36	3.53	0.910	0.152
Y6	Yes	17	3.65	0.786	0.191
	No	36	3.78	0.866	0.144
Y7	Yes	17	3.76	0.831	0.202
	No	36	3.81	0.749	0.125
Y8	Yes	17	3.59	1.004	0.243
	No	36	3.86	0.762	0.127
Y9	Yes	17	3.53	0.717	0.174
	No	36	3.58	0.806	0.134
Y10	Yes	17	3.47	1.007	0.244
	No	36	3.69	0.749	0.125
Y11	Yes	17	3.53	0.717	0.174
	No	36	3.75	0.841	0.140

Source: developed by L.M. Nguyen, L.V. Nguyen.

Table 5

Independent-samples t-test results comparing the means of DT-related items (Y1–Y11) between organizations implementing and not implementing BIM

Independent Samples Test										
N Assumed/Not		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95 % Confidence Interval of the Difference	
									Lower	Upper
Y1	Assumed	3.753	0.058	0.061	51	0.951	0.015	0.240	−0.466	0.496
	Not assumed.			0.055	24.934	0.956	0.015	0.265	−0.531	0.561
Y2	Assumed	0.011	0.915	.065	51	0.948	−0.016	0.250	−0.518	0.485
	Not assumed.			−0.065	31.472	.0948	−0.016	0.250	−0.526	0.493
Y3	Assumed	0.000	0.988	0.888	51	0.379	0.225	0.254	−0.284	0.735
	Not assumed.			0.868	29.761	0.392	0.225	0.260	−0.305	0.756
Y4	Assumed	5.652	0.021	−0.579	51	0.565	−0.165	0.285	−0.737	0.407
	Not assumed.			−0.503	22.982	0.620	−0.165	0.328	−0.844	0.514
Y5	Assumed	1.137	0.291	0.477	51	0.636	0.119	0.250	−0.383	0.622
	Not assumed.			0.523	39.962	0.604	0.119	0.228	−0.341	0.580
Y6	Assumed	0.023	0.879	−0.528	51	0.600	−0.131	0.248	−0.628	0.366
	Not assumed.			−0.547	34.417	0.588	−0.131	0.239	−0.616	0.355
Y7	Assumed	0.231	0.633	−0.179	51	0.859	−0.041	0.228	−0.499	0.418
	Not assumed.			−0.172	28.691	0.864	−0.041	0.237	−0.526	0.444
Y8	Assumed	3.123	0.083	−1.097	51	0.278	−0.273	0.249	−0.772	0.226
	Not assumed.			−0.994	25.040	0.330	−0.273	.275	−0.838	0.293
Y9	Assumed	0.430	0.515	−0.235	51	0.815	−0.054	0.229	−0.514	0.407
	Not assumed.			−0.245	35.072	0.808	−0.054	0.220	−0.500	0.392
Y10	Assumed	3.055	0.087	−0.907	51	0.369	−0.224	0.247	−0.719	0.272
	Not assumed.			−0.816	24.678	.422	−0.224	0.274	−0.789	0.342
Y11	Assumed	0.396	0.532	−0.932	51	0.356	−0.221	0.237	−0.696	0.255
	Not assumed.			−0.987	36.477	0.330	−0.221	0.223	−0.674	0.232

Source: developed by L.M. Nguyen, L.V. Nguyen.

Table 6

One-way ANOVA results comparing DT-related item scores (Y1–Y11) across different organizational roles

ANOVA						
N Dispersion		Sum of Squares	df	Mean Square	F	Sig.
Y1	Between Groups	3.366	4	0.841	1.327	0.274
	Within Groups	30.445	48	0.634		
	Total	33.811	52			
Y2	Between Groups	4.409	4	1.102	1.636	0.181
	Within Groups	32.345	48	0.674		
	Total	36.755	52			
Y3	Between Groups	5.343	4	1.336	1.932	0.120
	Within Groups	33.185	48	0.691		
	Total	38.528	52			
Y4	Between Groups	6.379	4	1.595	1.831	0.138
	Within Groups	41.810	48	0.871		
	Total	48.189	52			
Y5	Between Groups	8.762	4	2.190	3.721	0.010
	Within Groups	28.257	48	0.589		
	Total	37.019	52			
Y6	Between Groups	5.126	4	1.282	1.973	0.114
	Within Groups	31.176	48	0.649		
	Total	36.302	52			
Y7	Between Groups	1.235	4	0.309	.503	0.734
	Within Groups	29.482	48	0.614		
	Total	30.717	52			
Y8	Between Groups	1.824	4	0.456	.617	0.652
	Within Groups	35.459	48	0.739		
	Total	37.283	52			
Y9	Between Groups	2.522	4	0.631	1.062	0.386
	Within Groups	28.497	48	0.594		
	Total	31.019	52			
Y10	Between Groups	3.613	4	0.903	1.320	0.276
	Within Groups	32.839	48	0.684		
	Total	36.453	52			
Y11	Between Groups	8.477	4	2.119	4.057	0.007
	Within Groups	25.071	48	0.522		
	Total	33.547	52			

Source: developed by L.M. Nguyen, L.V. Nguyen.

Conclusion

This study explored how DT services influence the adoption of BIM in construction project management by surveying a diverse group of professionals and applying rigorous statistical analysis. The research provides empirical evidence that DT technologies play a meaningful role in strengthening BIM-based practices.

Beyond validating the connection between DT and BIM, the study uncovers nuanced differences in perception among different organizational roles — consultancy firms. In particular, they appear to recognize greater benefits from DT-enabled workflows than contractors and research institutions.

The results contribute to the broader discourse on digital transformation in the Architecture, Engineering, and Construction sector.

Despite its contributions. The study has limitations that open avenues for future research, such as the relatively small sample size.

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