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Research Article

Analyzing the Variances in Perspectives on BIM Implementation among Korea AEC Participants

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The goals and benefits of implementing building information modeling (BIM) in different facilities are comparable, although there are variations in the employed technologies. Nevertheless, when considering the practical aspects of BIM, the specific variations in implementing BIM across different facilities lack clarity. This study investigated the variations in viewpoints among participants in the architecture, engineering, and construction (AEC) industry regarding the adoption of BIM. The objective was to assess the necessity of developing diverse BIM application strategies based on the specific needs of AEC facilities. The following outlines the investigative process: (1) The survey questions were structured as items that necessitate prior investigation and consultation of BIM execution plans from prominent countries. (2) Appropriate statistical tests were chosen to analyze the correlation between respondents' information and the questions. (3) The findings of the analysis conducted on the group of respondents were deliberated. The survey revealed that strategic variations are essential for the implementation of space for meetings in a technical setting, the formulation of data standards and BIM team for a cooperative environment, and the assessment of subjects based on the type of facility. Specifically, client-specified common data environments exhibited variations in the responsibilities of participants, while the assignment of BIM coordinators also displayed differences in participant roles, depending on the type of facilities involved. Nevertheless, all participants were in complete agreement regarding the collaborative environment, technical environment, organizational structure, implementation guide, and the necessity for evaluation. Surveys of the perceptions of these AEC participants help identify factors that may hinder collaboration in advance and assist in adjusting communication and collaboration strategies. The BIM implementation strategy, which considers variations depending on the type of facility and the role of participants, facilitates seamless collaboration throughout the project and helps establish forward-thinking guidelines for BIM operations from the standpoint of the client and governance.

1. Introduction

Building information modeling (BIM) is now being utilized in a wide range of facilities beyond vertical architecture, including airports, roads, bridges, subways, and railways [1–5]. Infrastructure projects are utilizing BIM to incorporate laser scanning and integration, as well as merging with geographic information systems (GISs), road design, and planning [6]. The airport project utilized the BIM framework to facilitate digital design, operation, and construction lifecycle management, taking into account existing data and operational needs [7]. The implementation of BIM greatly facilitated the enhancement of electrification in the UK's railway infrastructure. BIM was instrumental in ensuring the seamless installation of new processing line equipment, assessing potential conflicts with existing bridges, and reconstructing the signal head array by means of signal monitoring [3]. Transportation projects specifically aid in prioritizing operational and maintenance duties and can facilitate the development of methods to evaluate and tackle imminent risks in order to allocate budget resources more effectively [2]. Bridges have been found to provide approximately

5%–9% savings during the construction period by contributing to the reduction of change orders and rework and have the potential to achieve cost savings during construction and subsequent projects [8].

Several studies have surveyed architecture, engineering, and construction (AEC) participants' opinions on the benefits and barriers of BIM application to identify potential issues and areas for improvement in BIM implementation. Hong Kong participants identified better cost prediction and control, efficient planning and management, and improvement in design and project quality as significant advantages of BIM implementation. They also highlighted stakeholders' resistance to fundamental change, inadequate organizational support and structure, and a lack of BIM-related industry standards as barriers [9]. In developing countries in the Middle East and North Africa, there were significant differences in the perception of BIM adoption barriers between BIM users and non-BIM users [10]. BIM users perceived financial barriers as the biggest obstacle, while non-BIM users identified structural and technical barriers. A survey of Nigerian architectural professionals revealed that overcoming 10.5% of BIM barriers is associated with improved BIM recognition and usage. Olanrewaju et al. [4] identified BIM barriers related to technology and business, cost and standards, training and people, and process and economics. Furthermore, Chinese AEC participants highlighted that the strategies for implementing BIM can vary depending on the type of AEC facility and can be enhanced by project experience, despite the consensus on the benefits and barriers of BIM [11].

Differences were found in the perception of BIM barriers between users who believed that the financial burden should be addressed first and nonusers who believed that structural problems should be addressed first [10]. Differences in perception among participants in BIM projects can hinder communication during project execution and the agreement for creating the BIM execution plan (BEP). The BEP is one of the documents submitted along with the contract before starting a BIM application project and is required to enhance efficiency and transparency in public construction projects [12]. However, overlooking differences in opinions among stakeholders in the project, as the BEP only addresses the agreed-upon results, can pose risks that hinder smooth collaboration. These potential barriers to communication can lead to conflicts and tensions among individuals or teams, a loss of trust, and decreased productivity by missing opportunities for problem-solving [13–15]. Investigating the differences in perception among AEC participant groups that may be overlooked during the BEP writing process and proactively addressing factors that hinder collaboration by adjusting communication and collaboration strategies is necessary for successfully achieving project goals. Especially in Korea, where different government agencies order different kinds of AEC buildings, considering how different groups of people see things when changing how people work together can help set up progressive governance for BIM implementation.

This study investigated the different points of view among AEC participants to come up with effective ways to help people work together and communicate, as well as different BIM application strategies for different types of facilities. The aim was to identify potential communication barriers and determine which items exhibit differences due to participant opinions during the collaboration process for the BEP. Additionally, the study aimed to examine whether strategic differences for BIM implementation are necessary based on facility types. This study assumes that there are differences of opinion among stakeholders in the construction, railway, and road sectors regarding prior consents for BIM implementation. The survey questions were constructed by organizing prior consent elements from previous studies and BEPs of major countries that project participants should agree on in advance. The data collected through the survey was analyzed using various appropriate statistical tests for the constructed questions. The analysis results reveal factors that are commonly or differently recognized among construction participants in relation to BIM implementation. Differences in opinions among participants classified by facility type can contribute to the development of an appropriate BIM implementation strategy for public institutions that commission other facility construction projects. Additionally, the absence of statistically significant differences neutralizes the need for differentiated BIM strategies for each facility type. However, if differentiation is necessary, it serves as a basis for expanding the scope to include factors beyond those mentioned in the BEP. Despite participants' differing opinions, the research results will monitor long-term changes in BIM implementation and identify preferred directions for BEP evaluation.

2. Prior Consent Elements for BIM Implementation

The implementation of BIM encompasses not only technical aspects but also organizational, regulatory, and administrative tasks [11, 12, 16, 17]. A BEP is a comprehensive document that outlines the agreements made among project participants regarding project goals, scope, requirements, model management, collaboration, data exchange methods and tools, and schedule. Project participants prepare this document before initiating the project [18, 19]. Countries that encourage the adoption of BIM provide BEP templates through BIM guides. The study refers to a BEP template that is an annex to the guidelines issued by the Construction Project Information Committee (CPIC) in the UK. These guidelines provide instructions for managing construction project information and documents in the UK. Additionally, the template is referenced by General Services Administration (GSA), which provides building management and support services for the US federal government and agencies, and the American Institute of Architects (AIA)'s Document G203. The study also mentions the guidelines published by South Korea's Ministry of Land, Infrastructure and Transport (MOLT) and Singapore's Building and Construction Authority (BCA). The table of contents for BEP templates, as announced by each country, exhibits varying organizational structures. These templates can be categorized into sections such as overview, goal and use, technique, collaboration, organization, and deliverable [20]. Figure 1 shows the reclassified contents of BEP templates that have been published in the UK, Singapore, US, and South Korea.

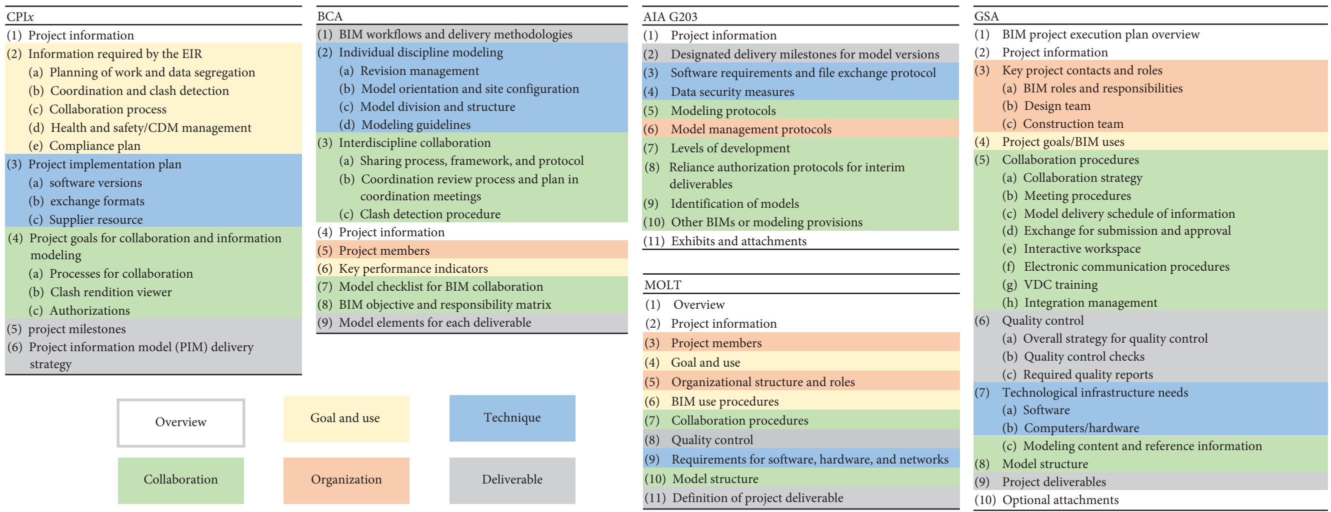

FIGURE 1: Components in the BEP table of contents: UK, Singapore, US, and South Korea.

The overview aligns with the project information provided in the bidding guide, while customizing the goal and use based on the project's complexity, scale, and specific requirements is possible [18, 21]. The technical environment encompasses various components such as software, hardware, and model structures. Collaboration entails the exchange of information and coordination procedures among workers or teams, including the use of model checklists and level of development. The deliverable encompasses outcomes that accurately represent the model's framework, the software employed, and the specifications outlined in the bidding guide and requested by clients. Technology, collaboration, organization, and delivery are crucial for developing comprehensive plans, whereas goal and use concentrate on presenting a general direction [22]. This study carefully analyzed the previous research's consent elements in relation to technology, collaboration, and organization. Its main objective was to address and resolve project-related issues by emphasizing practical implementation and execution.

The establishment of a technical environment requires the expenditure of funds for the acquisition of software and hardware. Previous studies have consistently identified the expenditure of funds for the acquisition of software and hardware as a hindrance to the implementation of BIM, as mentioned by Dainty et al. [23], Porwal and Hewage [24], and Rogers et al. [25]. Prior research has demonstrated that collaborative physical environments decrease both the amount of time spent and the loss of information when engaging with other specialists [26–28]. The BEP templates provided by GSA incorporate an interactive workspace for facilitating collaboration in procedural matters. Collaborative spaces necessitate the presence of tools that enable participants to examine 3D models efficiently and precisely. Users' perception and interaction can be affected by the type of display device used [28]. Collaborative spaces that accommodate multiple attendees and include hardware components can be classified as part of the technological environment.

Furthermore, previous studies related to collaboration have mentioned standard data, the definition of collaboration processes, and the use of common data environment (CDE). The lack of BIM data standards is a hindrance to BIM implementation, as the definition of BIM standards influences the scope and methods of data exchange among participants for collaboration [9, 29]. Alongside the definition of collaboration processes, the use of cloud-based collaboration systems in a CDE has been proven to enhance collaboration among team members and increase work efficiency through the creation of automated master information delivery plans [21]. As shown in Figure 1, collaboration processes are commonly addressed as significant content in each country's BEP, and the work processes for collaboration are crucial contractual terms affecting BIM implementation [18]. During the early stages of design, participants can use CDE as a digital information silo and a platform that enables real-time synchronous collaboration to identify conflicts found in BIM and resolve coordination issues [30].

Forty-five percen of general contractors in the United States outsource BIM in terms of organizational composition. General contractors recognize that there are concerns about communication gaps and quality degradation and that in-house BIM implementation has a more positive impact on projects than outsourcing. However, they continue to outsource due to the uncertainty of an immediate return on investment and the reduced risks of adopting new technologies [31]. It is necessary to allocate a BIM coordinator within the organization to manage information and communication flow, monitor and adjust design changes, and act as a boundary spanner [32].

Since it has been more than a decade since the UK, Singapore, US, South Korea, and other countries first announced their BIM guidelines, it is necessary to present advanced strategies and guidelines that consider the opinions of participants in operational evaluation from a client and governance perspective, leading the ordering of BIM projects and providing BEP templates [11, 33, 34]. The unavailability of guidelines has been identified as the biggest barrier to BIM implementation in some countries, such as China and Malaysia [12, 35] found that subcontractors' use of BEP is related to the success

Table 1: Prerequisite for BIM implementation: consent elements among participants.

Elements		Source
Technical environment	Collaborative space	[3, 11, 19, 26, 28, 44]
	HW and SW	[18, 23–25]
Collaborative environment	Standard data	[45–48]
	CDE platform	[19, 21, 29, 30, 49–51]
	Task, process	[18, 30, 46, 47, 52, 53]
Organization	Configuration of team	[9, 19, 31, 54, 55]
	Coordinator/manager	[24, 26, 32, 52]
Execution guide	Revision strategy	[20, 23, 25, 35, 52]
	Detailed definition of collaboration	[17, 18, 30, 46]
Evaluation	Appraisee	[36, 56]
	Postexecution review	[41–43, 57]
	Process and criterion	[36, 38, 40, 41, 43, 56, 57]

of project costs. Examining the need to redefine organizations, tasks, and roles included in the BIM guide and reviewing detailed procedures regarding collaboration is necessary. However, the provision of standardized workflows may conflict with the BEP customization of participants to meet the requirements of a particular contract, procurement, or project [17, 20]. Therefore, it is necessary to establish a revision strategy for the BIM guide that incorporates the opinions of participants with BIM experience.

Researchers have proposed various measurements in BIM evaluation, including BIM maturity [36, 37], which focuses on evaluating organizational or individual capabilities, the degree of goal achievement [38], return on investment [39], and qualitative value assessed by participants based on the quantities reviewed from BIM [40]. There are two perspectives in the evaluation: one evaluates BIM capabilities, resources, and competencies [33, 41] to effectively select and qualify BIM teams or project participants due to lack of ordering experience, while the other is a postexecution evaluation that identifies the impact on project performance and incorporates it into subsequent projects [41–43]. Since guidelines in countries with insufficient BIM experience tend to prioritize the former over the latter, it is necessary to investigate the need for post-BIM evaluation to revise and improve the guidelines. Additionally, it is important to survey user opinions on evaluation subject and standards, as these can vary across different organizations and projects.

To summarize, prior research has examined how individuals perceive the advantages and obstacles of implementing BIM in different countries, including the United States, China, the Middle East, Hong Kong, and Nigeria. These studies have also highlighted the necessity of employing distinct strategies based on the type of AEC facilities. To progress BIM, it is crucial to analyze the BIM strategies utilized in various settings for each AEC facility. Factors pertaining to the technical environment, collaborative environment, organization, execution guide, and evaluation were identified from previous research (Table 1). These factors necessitate the agreement of participants to formulate a BEP and carry out a survey of AEC participants' viewpoints. Nevertheless, in this study, collaborative spaces were categorized as technical settings rather than collaborative settings. Given the intended function and utilization of the area, it is imperative to incorporate collaborative spaces within collaborative environments. Nonetheless, the installation of equipment in the collaborative space for model verification is primarily associated with the technical environment, hence its inclusion.

3. Survey Design and Collection

The study designed survey questions and options to distinguish responses to the five prior consent elements for BIM application among participants in construction projects divided into architecture, infrastructure, and railways. In addition to the 18 questions (Table 2) categorized into technical environment, collaborative environment, organization, execution guidelines, and evaluation, basic information was included to identify respondent types. Respondents' basic information consisted of affiliation (Q1), business field (Q2), expertise area (Q3), career (Q4), the number of BIM experiences (Q5), and level of BIM utilization at work (Q6). Questions 5 and 6 were included to investigate the relation between the level of BIM utilization and the number of participants in BIM, as BIM is not applied to all construction projects and the number of participants can vary depending on the respondent's experience.

The scale for measurement was designed to consider the content of the question and the convenience of the response and to reflect the expected response without overlapping attributes by setting up options (Table 2). The questions about the respondents' basic information (Q1–Q6) were designed using five categorized nominal scales. For example, respondents classified the types of agencies (Q1) as (a) client agency, (b) designer, (c) contractor, (d) academic, and (e) Etc. In addition, the business field (Q2) and expertise area (Q3) followed the response types in Table 2 and were designed as nominal scales. Career (Q4), BIM experience (Q5), and utilization (Q6) were designed as ordinal scales, increasing by year, frequency, and level. Career (Q4) was calculated to be up to 30 years, considering that the legal retirement age is 60 and the average age of entering society is 30. Since its

Table 2: Design questions and options.

Question			Number	Options	Scale
Basic information		Affiliation	Q1	(a) CA, (b) DEC, (c) contractor, (d) academic, (e) Etc.	Nominal
		Business field	Q2	(a) Building, (b) infrastructure, (c) rail, (d) IT	
		Expertise area	Q3	(a) Operation, (b) construction, (c) D&I, (d) BSP, (e) Etc.	
		Career	Q4	(a) Below 5 years, (b) 5–10 years, (c) 11–20 years, (d) 21–30 years, (e) over 30 years	Ordinal
		BIM experience	Q5	(a) None, (b) 1–2x, (c) 3–5x, (d) 6–9x, (e) over 10x (project count)	
		Perceived BIM utilization level	Q6	(a) Very high, (b) high, (c) middle, (d) low, (e) very low	
Technical environment	BIM room	Necessity	Q7	(a) Not necessary, (b) neutrality, (c) absolutely necessary	Nominal
		Seat capacity	Q8	(a) 5–10 persons, (b) 10–20 persons, (c) 20–30 persons, (d) over 30 persons, (e) Etc.	Ordinal
		Located close to	Q9	(a) Client, (b) design team, (c) on-site, (d) BIM agency, (e) anywhere (multichoice)	Nominal
		Critical task	Q10	(a) Design review, (b) coordinate interface, (c) quality check, (d) simulation, (e) precon, (f) value engineering	Seven points interval for each type
	Hardware	Devices necessary to BIM room	Q11	(a) Interactive whiteboard, (b) projector, (c) high-performance PC, (d) HMD, joystick for VR, (e) videoconferencing devices	
	Software	License provider assigning to whom	Q12	(a) Client, (b) designer or contractor, (c) BIM service provider	Nominal
Collaborative environment		Define data standards	Q13	Not necessary, neutrality, strongly necessary	Seven points interval
		CDE platform development	Q14	(a) Server vs. cloud service, (b) specialized in client, (c) commercial solution, (d) wed, mobile access	
		Important task	Q15	(a) Arrange collaborative task, (b) subtask definitions, (c) coordinator appointment, (d) training coordinator, (e) defining participant's role, (f) process improvements, (g) attendance at meetings of supervisory, (g) attendance at meetings of supervisory, (h) guidance revision	
Organization		Current situation	Q16	(a) Existing part responsible, (b) another part by reorganization, (c) not assigned	Nominal
		Future expectation	Q17	(a) Necessary BIM team, (b) outsourcing to BIM agency, (c) temporary with BIM agency	
		Necessity for full-time coordinator	Q18	(a) Not necessary, (b) neutrality, (c) strongly necessary	
		Coordinator allocated to whom	Q19	(a) Client, (b) designer, (c) contractor, (d) BIM agency	
Execution guide		Revision strategy of guidelines	Q20	(a) Must include organization, responsibilities, roles, (b) organization, roles in the terms of reference, (c) early include establish	
		Essential definition for collaboration	Q21	(a) Organization and roles, (b) subtasks and procedure, (c) criterion for competency evaluation	Seven points Interval
Evaluation		Appraisee	Q22	(a) Company, (b) manager, (c) BIM service provider, (d) temporarily to company, expanded to BIM team	Nominal
		Need for postexecution review	Q23	Not necessary, neutrality, strongly necessary	Seven points Interval
		Process and criterion	Q24	(a) Establishing criteria, (b) organize a committee, (c) objective and quantitative evaluation by achievement level, (d) qualitative evaluation, (e) weighted value by difficulty and importance	

introduction in Korea, the home country of the survey subjects, BIM experience (Q5) has been less than 20 years, with the maximum set at 10 times, assuming a general construction period of 2–3 years. The interval was divided into four sections up to the calculated maximum, and the final option was defined as exceeding the maximum.

Questions and options, excluding basic information (Q7–Q24), were constructed based on the prior consent elements mentioned in the preceding study. The design of Q7 and Q18, which inquire about the necessity of a full-time coordinator in the BIM room, prioritized clear positions of approval and opposition over neutrality of response. A nominal scale of three points, (a) not necessary, (b) neutrality, and (c) absolutely necessary, was utilized to enhance response speed and ease. The capacity of the BIM room (Q8) was defined in four ranges based on 30 people and others, and the location of the BIM room (Q9) was designed as a nominal scale, taking into consideration contractual relationships and organization. Q9 was composed of multichoice options to investigate preferences for each response item (a) client, (b) design team, (c) on-site, (d) BIM agency, and (e) anywhere, rather than comparing response types.

For quantitative data analysis, we designed other questions (Q10–Q11, Q13–Q15, Q21, and Q23–Q24) as an interval scale. We selected a seven-point semantic differential scale that reflects discrimination between positive and negative opinions [58]. The Likert scale, commonly used to evaluate individual attitudes or values, requires effort and time for respondents to understand the presented questions and indicate their level of agreement, often resulting in a tendency to choose excessively positive, negative, or neutral responses [59, 60]. However, respondents can quickly provide feedback on opinions divided into positive and negative categories using the semantic differential scale, as they can choose a position that aligns with their own thoughts between the two opposing opinions of "necessary" and "unnecessary" [61]. For example, Q10 asked whether six tasks (a–f) such as design review, coordinate interface, quality check, simulation, preconstruction, and value engineering must be performed in the BIM room. Furthermore, the examples were categorized on a seven-point scale, ranging from "must be performed" to "must not be performed." A score of three points was assigned to "must be carried out," zero points to "neutral," and −3 points to "must not be carried out."

This study put responses into groups based on the basic information (Q1–Q6), as shown in Table 1. It then tested hypotheses about the groups of responses to see if there were differences in the participants' points of view. The selection of the hypothesis testing method was based on an analysis of the data's characteristics pertaining to the designed questions. The survey, utilizing the data from Table 1, was disseminated to Korean construction sector participants through email and social media platforms between June and August 2022. A grand total of 54 responses were gathered, and the response rate for the 24 questions in the collected data was computed. Seven participants had a response rate below 50%. The survey analysis comprised 47 cases, in which over 50% of the total questions were answered. However, five respondents with a response rate of 50% or less were excluded as outliers. Based on the observed data's distribution, the selection of the analysis method considered the characteristics of each question and the distribution of the data to be analyzed.

4. Data Analysis and Result

4.1. Selection for Survey Test. Using the programing language *R*, this study tested hypotheses about the features and distribution of variables that could be statistically confirmed from the collected data and investigated the differences among the construction participants. The independent variable (IV) for establishing the hypothesis was set as the respondent's basic information (Q1–Q6), and the dependent variable (DV) was set as BIM implementation factors (Q7–Q24). The null hypothesis states that there is no difference in opinion on the DV among participant groups classified by the IV, while the alternative hypothesis suggests the presence of a difference in opinion. For example, the null hypothesis (H0) and the alternative hypothesis (H1) for verifying the relationship between variables Q1 and Q7 are as follows:

H0: Participants sorted by affiliation (Q1) do not differ in the necessity of the BIM room (Q7).

H1: Participants sorted by affiliation (Q1) differ in the necessity of the BIM room (Q7).

In Table 2, IVs (Q1–Q6) are nominal and ordinal scales, and DVs (Q1–Q6) are nominal, ordinal, and interval scales. Therefore, researchers should apply different tests to each combination of these variables. For instance, if Q1 is the IV and Q7 is the dependent variable (DV), both are categorical data. The chi-square test and Fisher's exact test can be used to confirm the relationship between these categorical variables [62, 63]. However, the chi-square test is not valid in this study due to the low expected frequency count to estimate the sample size of Q1 and Q7 from 47 filtered survey data. Therefore, the study adopted the Fisher's exact test as the testing method for nominal variables.

Ordinal correlation analysis was used to examine the association between variables and ordinal scales, as shown in Q4 and Q5 of Table 2. *t*-tests, analysis of variance (ANOVA), Kruskal–Wallis, and Mann–Whitney *U* tests can be applied to variables with interval, nominal, and ordinal scales [9–11, 62]. Since the IVs Q1–Q6 of this study are divided into four to five groups (Table 2), the *t*-test and Mann–Whitney *U* test, which examine differences between two independent groups, are not appropriate. To satisfy the assumptions of independence, homogeneity of variances, and normality, an ANOVA is used to test the average difference among three or more groups. The results of performing Shapiro–Wilk and Lilliefors tests, which are used when the sample size is small, are displayed in Table 3 to check the assumption of normality. In Table 3, when the W value is closer to 1, the D value is closer to 0, and the P-value is greater than 0.05, the normality assumption is satisfied. However, in Table 3, there are no P-values above 0.05 for any variable, indicating that the assumption of normality is not satisfied. Therefore, ANOVA is not suitable

Table 3: Normality test of the interval variables.

Test	Shapiro–Wilk		Lilliefors	
Variables	W	P-value	D	P-value
Q11-a	0.827	6.90.E-06	0.336	8.99.E-15
Q11-b	0.833	9.52.E-06	0.220	5.40.E-06
Q11-c	0.715	3.06.E-08	0.230	1.38.E-06
Q11-d	0.898	6.06.E-04	0.223	3.49.E-06
Q11-e	0.789	9.08.E-07	0.304	6.71.E-12
Q10-a	0.853	3.19.E-05	0.202	5.13.E-05
Q10-b	0.833	9.56.E-06	0.222	3.82.E-06
Q10-c	0.851	3.18.E-05	0.198	1.05.E-04
Q10-d	0.883	2.10.E-04	0.158	4.71.E-03
Q10-e	0.826	6.25.E-06	0.211	1.61.E-05
Q10-f	0.917	2.55.E-03	0.172	1.26.E-03
Q13	0.730	5.86.E-08	0.345	1.33.E-15
Q14-a	0.770	4.40.E-07	0.316	1.14.E-12
Q14-b	0.827	6.61.E-06	0.226	2.27.E-06
Q14-c	0.872	1.46.E-04	0.165	3.41.E-03
Q14-d	0.784	8.67.E-07	0.264	1.24.E-08
Q15-a	0.797	1.38.E-06	0.279	5.66.E-10
Q15-b	0.815	3.46.E-06	0.249	8.66.E-08
Q15-c	0.818	4.20.E-06	0.216	8.21.E-06
Q15-d	0.859	5.22.E-05	0.237	7.00.E-07
Q15-e	0.808	2.39.E-06	0.249	7.81.E-08
Q15-f	0.865	6.73.E-05	0.200	6.00.E-05
Q15-g	0.807	2.25.E-06	0.256	2.67.E-08
Q15-h	0.813	3.08.E-06	0.262	1.10.E-08
Q21-a	0.807	3.43.E-06	0.280	1.29.E-09
Q21-b	0.780	8.98.E-07	0.284	6.94.E-10
Q21-c	0.812	4.39.E-06	0.223	5.99.E-06
Q23	0.885	4.64.E-04	0.199	1.73.E-04
Q24-a	0.906	1.95.E-03	0.192	3.73.E-04
Q24-b	0.903	1.39.E-03	0.176	1.55.E-03
Q24-c	0.883	3.50.E-04	0.184	6.78.E-04
Q24-d	0.871	1.59.E-04	0.179	1.14.E-03
Q24-e	0.890	5.40.E-04	0.193	2.88.E-04

for analyzing the data investigated in this study. This study adopted the Kruskal–Wallis test to analyze the differences in means between the IVs (Q1–Q6) and the dependent variables (Q1–Q6) because the Kruskal–Wallis test can be applied when the assumption of normality is violated in any of the three or more groups. Additionally, the Dunn test was used for post-hoc analysis. If the P-value in the Kruskal–Wallis results falls below the significance level, researchers reject the null hypothesis and accept the alternative hypothesis, which requires conducting post-hoc analysis to examine the groups with significant mean differences [62].

The hypothesis verification method applied in this study, considering the sample size and variables discussed thus far, is illustrated in Figure 2. If the IV and DV are nominal and have a single response, conducted Fisher's exact test. A cross-analysis using frequency and contingency tables was performed for the nominal IV (Q9) with multiple responses, as observations could belong to more than one category. The Kruskal–Wallis and Dunn tests were applied to examine the relationship between the nominal IV and the interval-dependent variable. Additionally, the Spearman correlation analysis revealed linear relationships among the ranking variables (Q4–Q6).

4.2. Analysis. Before testing the hypothesis, this study examined the different types of people who answered the filtered survey data by making mosaic graphs for some IVs Q1, Q2, and Q5. Figure 3 shows the results. The X-axis of the figure represents the business field (Q2), which is divided into building, infrastructure, railway, and information technology (IT). The Y-axis represents the frequency of participation in BIM projects (Q5), and the legend represents the affiliation type (Q1) of the organizations participating in construction projects. In the mosaic graph, the size of each block represents the relative ratio of respondents of that type, and the numbers in parentheses within the blocks represent the number of observed responses. There are a total of 12 respondents from the building field, with one of them belonging to the contractor category and having no experience in applying BIM. Blocks in building with one or two instances of BIM experience were classified into the three IVs in an even way, with two respondents in each of the groups for CA, DEC, contractor, and academic. However, there were no respondents belonging to CA on the road and no respondents belonging to the designer and construction company in the group with less than five BIM participations on the railroad. Other blocks, excluding building, did not show a relatively diverse group of respondents in terms of affiliation type. Analysis based on two or more combinations of IVs, as shown in Figure 3, has limitations due to the limited number of observed responses and lack of representativeness.

In the legend of Figure 3 (Q1), "others" refer to types that do not belong to business owners, planners, engineers, builders, or academia. These types include IT groups involved in CDE development, BSPs providing BIM generation and authoring tools, and individuals affiliated with BIM-related R&D departments. As a result, the IT group had many respondents categorized as "others" in Q1, and the infrastructure and railway groups also had similar classifications. This confirms that the BIM project involves organizations that are different from those in traditional construction. Since BIM applications are still in the research and development stage and no BIM projects have been ordered, the railway group has relatively limited types compared to architecture, which is divided into various types excluding IT groups. On the other hand, architecture is the first group to adopt BIM in Korea. However, at the time of the survey, three respondents who had more than three experiences with BIM in railways were participating in railway projects. However, it is estimated that their previous projects involved BIM projects in infrastructure or architecture, rather than railways. In particular, the lack of representation of respondents with six or more years of BIM experience in all fields limits the survey analysis by business field and BIM experience. This study only analyzed the relationship between single IV and DV.

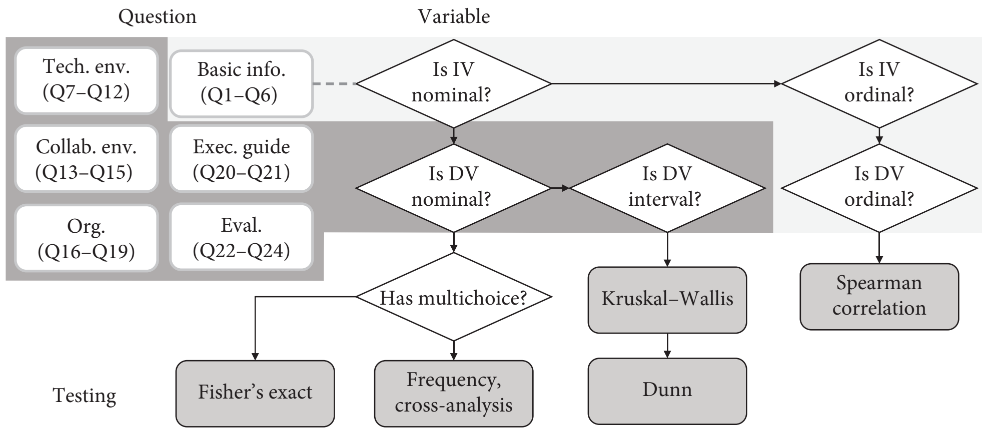

Figure 2: Survey test map.

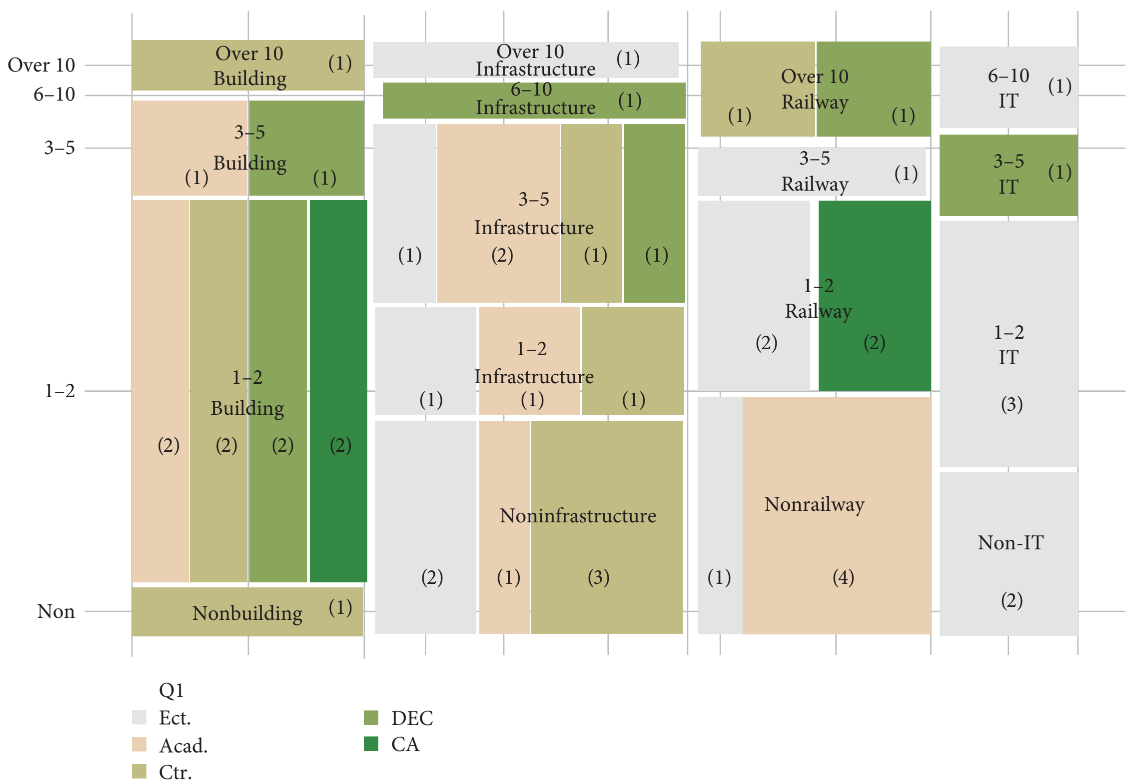

Figure 3: Mosaic plot of the respondent types.

Table 4 presents the results of a Spearman correlation analysis to determine the linear relationships between ordinal variables (Q4–Q6). Table 4 shows that there was a positive correlation between the respondents' career (Q4), the number of BIM participations (Q5), and the level of BIM utilization (Q6). This was shown by a P-value of less than 0.05 and a correlation coefficient greater than 0. However, the P-value for Q4 and Q6 is 0.448, indicating no correlation between Q4 and Q6. The reason for the lack of correlation between work experience (Q4) and the level of BIM utilization in one's work (Q6) is that Q4 represents an industrial career, not a BIM-related career. For BIM-related careers, one can refer to the number of BIM business participations (Q5). In summary, the analysis results indicate that as the level of work experience (industrial career) increases, the number of BIM business participations also increases, and

Table 4: Analysis of the Spearman correlation for Q4–Q6.

r (P-value)	Q4	Q5	Q6
Q4	1.000	0.506 (0.0003)	0.113 (0.448)
Q5	—	1.000	0.458 (0.0012)
Q6	—	—	1.000

Table 5: P-value for the Fisher`s exact test.

P	Q1	Q2	Q3	Q4	Q5	Q6
Q7	0.662	0.290	0.975	1.000	**0.022**	0.222
Q8	0.371	0.444	0.312	0.201	0.925	0.641
Q12	0.378	0.702	0.112	0.789	0.809	0.271
Q16	0.122	0.604	0.365	0.070	0.958	0.156
Q17	0.826	0.324	0.968	0.487	0.857	0.403
Q18	0.425	0.184	0.967	0.906	0.180	0.714
Q19	**0.003**	**0.017**	0.111	0.492	0.958	0.543
Q20	0.348	0.295	0.226	0.167	0.591	0.507
Q22	0.647	**0.018**	0.505	0.399	0.176	0.531

as the number of BIM participations increases, the level of BIM utilization in one's work also increases. To anticipate the level of utilizing BIM in your work, it is more appropriate to refer to your experience in participating in BIM projects rather than your industrial career.

Table 5 shows the results of the Fisher's exact test, confirming the relationship between nominal variables. The bold underlined numbers indicate P-values of 0.05 or less, while the underlined numbers indicate P-values of 0.1 or less and 0.05 or more. No statistical evidence was found to suggest differences in BIM application opinions among project participants and between sectors, as most variables had P-values of 0.1 or higher. These results indicate that the null hypothesis (H0) is accepted at P-values greater than 0.1, leading to the rejection of the alternative hypothesis (H1). On the other hand, the following four items showed significant differences with P-values less than 0.05: (a) the necessity of collaborative space (Q7) and BIM participation (Q5), (b) BIM coordinator designation (Q19) and affiliation (Q1), (c) BIM coordinator designation (Q19) and business field (Q2), and (d) evaluation (Q22) and business field (Q2). Additionally, when the significance level was raised to 0.1, relatively significant differences were observed in personal careers (Q4) and current BIM organizations (Q16). The significance level includes 0.01, 0.05, and 0.1. Typically, researchers apply a significance level of 0.05, but it can be increased if there is a lot of noise in the data or if the sample size is small [64]. In this study, the main criterion for focused analysis is a significance level of 0.05, considering the practical meaning and user experience of BIM recognition. The significance level of 0.1 was used as additional information. In this study, P-values of 0.05 or less were considered statistically significant, and nonsignificant P-values were avoided for dichotomous interpretation.

Table 6 presents the test results for the nominal IV and interval DV. The bold numbers underlined in Table 6 indicate P-values of 0.05 or less, while the underlined numbers represent P-values of 0.1 or less. Q1-divided responses showed P-values of less than 0.05 in Q14-b, Q14-d, and Q23. Additionally, Q2 exhibited P-values of 0.1 or higher in all questions except Q10-f and Q11-d. This suggests that there is no difference in the average among the construction, infrastructure, and railway groups. Q3 revealed average differences in Q14-b and Q23. Furthermore, Q4 did not show any significant differences with P-values of 0.1 or higher in all interval DVs. Q5 displayed P-values of less than 0.05 in Q15-b, Q21-b, and Q24-a. Q6 exhibited P-values of more than 0.05 and less than 0.1 in Q10-d and Q15-g.

The Kruskal–Wallis test detected differences between groups separated by IVs. The Dunn test found those differences that were less than the significance level P-value. Tables 7–10 display the Z-value and the P-value corrected by Bonnofari, which are the statistics of the Dunn test. The corrected P-value by Bonnofari was adopted to prevent an increased risk of error in the process of repeated hypothesis testing for cross-group comparisons. Table 7 presents the statistics and P-values from the Dunn test for the questions (Q14-b, Q14-d, and Q23), with differences found in the group separated by Q1. If the corrected P-value is below the significance level, it indicates a significant difference between the two groups. Q14-b showed a corrected P-value of less than 0.05 in Ctr:ect. and DEC:ect. In Table 7, the Z-value represents the average difference between each group. For example, the Z-value of Crt:ect, −3.127, indicates that the average of the builder (Ctr) is ect. It indicates that it is 3.127 lower than the group. In other words, builders responded that they do not need the client-specified CDE (Q14-b) more than other groups. Q14-d found significant differences between the academic and other groups, which is interpreted as the academic group needing less web or mobile-accessible CDE compared to IT jobs. Q23 showed significant differences between the DEC and ect. groups, and it is interpreted that DEC requires less postexecution review than the ect. group.

Table 8 presents the results of the Dunn test for the observed items (Q10-f, Q11-d) that showed an average difference in the business field (Q2). Q10-f exhibited P-values below 0.05 and negative Z-values in the building and rail groups, indicating a tendency for value engineering to be performed more in the BIM room than in rail. Furthermore, the Kruskal–Wallis test (Table 6) revealed that Q11-d exhibited P-values of 0.1 or less and 0.05 or more, suggesting that no P-value below 0.05 was observed in the Dunn test. Interpretation of Q11-d requires consideration of the data distribution.

Table 9 presents the results of the Dunn test for the observed average differences (Q10-a, Q10-e, Q14-d, and Q23) in the expertise area (Q3). Q10-a showed a significant difference between the D&S group and the ect. group. Considering a Z-value of 0.03, the results suggest that the D&S group is less likely to require design review in the BIM room compared to the ect. group. The Q10-e revealed a significant difference between the architect and BSP groups. The Z-value of 0.039 indicates that the architect was more likely to respond that preconstruction does not necessarily need to be performed in the BIM room compared to BSP. Q14-b showed differences between architect and ect., BSP and ect., both of which had negative Z-values. Therefore, the architect and BSP groups responded that they do not require a client-specified CDE solution compared to the other groups. The other groups classified by Q3 include respondents involved in R&D and IT, and client-specified CDE solutions can act as a burden on solution development and training for builders and BSP. Q23 found significant differences between BSP and other

Table 6: P-value for the Kruskal–Wallis test.

Question and response		Q1	Q2	Q3	Q4	Q5	Q6
Q10: Function of BIM room	(a) Design review	0.414	0.400	<u>0.067</u>	0.540	0.820	0.137
	(b) Coordinate interface	0.658	0.621	0.699	0.149	0.198	0.236
	(c) Quality check	0.156	0.571	0.202	0.776	0.689	0.248
	(d) Simulation	0.188	0.744	0.186	0.625	0.935	<u>0.066</u>
	(e) Preconstruction	0.621	0.306	<u>0.064</u>	0.874	0.725	0.856
	(f) Value engineering	0.270	<u>**0.041**</u>	0.617	0.316	0.747	0.981
Q11: Devices of BIM room	(a) Interactive whiteboard	0.310	0.359	0.270	0.231	0.928	0.241
	(b) Projector	0.701	0.488	0.169	0.166	0.948	0.558
	(c) High-performance PC	0.597	0.864	0.164	0.704	0.791	0.535
	(d) HMD, joystick for VR	0.161	<u>0.063</u>	0.306	0.445	0.330	0.643
	(e) Video conferencing	0.609	0.721	0.554	0.187	0.284	0.487
Q13: Need for data standard		0.758	0.680	0.490	0.196	0.131	0.359
Q14: CDE platform	(a) Storage; cloud vs. server	0.409	0.601	0.157	0.301	0.604	0.748
	(b) Specialized solution	<u>**0.002**</u>	0.346	<u>**0.003**</u>	0.207	0.842	0.608
	(c) Commercial solution	0.772	0.921	0.589	0.682	<u>0.063</u>	0.287
	(d) Wed, mobile accessible	<u>**0.045**</u>	0.608	0.123	0.176	0.733	0.116
Q15: Important task in collaborative environment	(a) Arrange collaborative task	0.688	0.898	0.388	0.133	0.365	0.892
	(b) Subtask definitions	0.617	0.773	0.642	0.464	<u>**0.042**</u>	0.343
	(c) Coordinator appointment	0.290	0.650	0.371	0.618	0.150	0.816
	(d) Training coordinator	0.900	0.970	0.459	0.747	0.864	0.867
	(e) Defining participant's role	0.290	0.281	0.851	0.680	0.265	0.700
	(f) Process improvements	0.821	0.532	0.308	0.727	0.856	0.927
	(g) Attendance at meetings of supervisory	0.112	0.655	0.547	0.702	0.730	<u>0.078</u>
	(h) Guidance revision	0.688	0.234	0.372	0.409	0.444	0.994
Q21: Definitions for collaboration	(a) Organization and roles	0.397	0.460	0.212	0.593	0.215	0.812
	(b) Sub-tasks and procedure	0.355	0.843	0.356	0.615	<u>**0.049**</u>	0.761
	(c) Establish criterion for competency evaluation	0.220	0.407	0.272	0.720	0.396	0.808
Q23: Need for postexecution review		<u>**0.038**</u>	0.840	<u>**0.017**</u>	0.620	0.705	0.841
Q24: Process and criterion	(a) Establish criteria internally for each stage	0.155	0.157	0.311	0.159	<u>**0.043**</u>	0.699
	(b) Composition of committees	0.496	0.790	0.378	0.573	0.424	0.258
	(c) Outcome-based assessment	0.385	0.758	0.414	0.524	0.221	0.507
	(d) Qualitative evaluation	0.701	0.886	0.742	0.571	0.128	0.259
	(e) Assigning a weighted value by difficulty and importance	0.835	0.966	0.768	0.621	0.269	0.214

Table 7: Statistics and P-value from the Dunn test by Q1.

Q1	(Q14-b) specialized CDE		(Q14-d) Wed, mobile-accessible CDE		(Q23) Need for postexecution review	
	Z	adj. P	Z	adj. P	Z	adj. P
CA:Ctr	2.491	0.064	−0.405	1.000	−0.538	1.000
CA:DEC	2.468	0.068	0.647	1.000	1.320	0.934
CA:Acad	1.751	0.400	0.865	1.000	−0.446	1.000
CA:ect.	0.350	1.000	−1.094	1.000	−1.112	1.000
Ctr:DEC	0.149	1.000	1.310	0.952	2.236	0.127
Ctr:Acad	−1.033	1.000	1.681	0.464	0.149	1.000
Crt:ect.	−3.127	**0.0088**	−0.921	1.000	−0.681	1.000
DEC:Acad	−1.085	1.000	0.216	1.000	−2.250	0.122
DEC:ect.	−2.949	**0.0159**	−2.231	0.128	−3.121	**0.0090**
Acad:ect.	−2.079	0.188	−2.762	**0.029**	−0.916	1.000

The bold underlined number represents a p-value below the significance level of 0.05.

Table 8: Statistics and P-value from the Dunn test by Q2.

(Q2) Business field	(Q10-f) Value engineering		(Q11-d) HMD, joystick for VR	
	Z	adj. P	Z	adj. P
Building:infra.	−1.254	0.630	−1.128	0.779
Building:rail.	−2.850	**0.0131**	−2.377	0.052
Building:IT	−1.230	0.656	0.123	1.000
Infra:rail.	−1.793	0.219	−1.413	0.473
Infra:IT	−0.234	1.000	1.080	0.841
Rail:IT	1.216	0.671	2.163	0.092

The underlined number represents a p-value below the significance level of 0.1, and the bold underlined number represents a p-value below the significance level of 0.05.

Table 9: Statistics and P-value from the Dunn test by Q3.

Q3	(Q10-a) Design review		(Q10-e) Preconstruction		(Q14-b) Specialized CDE solution		(Q23) Need for postexecution review	
	Z	adj. P	Z	adj. P	Z	adj. P	Z	adj. P
Opr:Ctr	0.138	1.000	0.242	1.000	−1.090	1.000	2.128	0.167
Opr:D&S	−1.377	0.843	−0.946	1.000	0.080	1.000	1.212	1.000
Opr:BSP	0.530	1.000	1.907	0.283	1.413	0.789	−0.361	1.000
Opr:ect.	−0.954	1.000	0.288	1.000	−1.262	1.000	−2.550	0.054
D&S:Ctr	−1.761	0.391	−1.366	0.860	1.250	1.000	−0.754	1.000
D&S:BSP	1.079	1.000	−0.897	1.000	−1.596	0.552	−1.038	1.000
D&S:ect.	−2.745	**0.030**	−0.878	1.000	−1.249	1.000	−1.078	1.000
Ctr:BSP	0.828	1.000	2.657	**0.039**	0.377	1.000	2.153	0.157
Ctr:ect.	−1.021	1.000	0.689	1.000	−3.059	**0.0111**	−0.331	1.000
BSP:ect.	−1.961	0.249	−2.216	0.134	−3.561	**0.0018**	−2.730	**0.032**

The underlined number represents a p-value below the significance level of 0.1, and the bold underlined number represents a p-value below the significance level of 0.05.

groups, with a tendency for BSP to think that postexecution review is not necessary compared to other groups, considering the negative Z-value. This is analyzed as being due to the direct impact of BIM work evaluation on BSP.

Table 10 presents the results of the Dunn test for items (Q14-c, Q15-b, Q21-b, and Q24-a), where average differences were observed in groups classified by expertise area (Q3). The groups without BIM experience and the groups with one to two experiences for Q24-a had adjusted P-values below 0.05. With a Z-value of −2.611, the group without BIM experience showed a somewhat less positive response to establishing evaluation criteria internally for each stage compared to the group with one to two experiences. Adjusted P-values above 0.05 and below 0.1 were observed for Q14-c, Q15-b, and Q21-b. Q14-c showed a difference between the groups with one to two BIM experiences and the groups with

Table 10: Statistics and P-value from the Dunn test by Q5.

(Q5) BIM experience	(Q14-c) Commercial solution		(Q15-b) Subtask definitions		(Q21-b) Subtasks and procedure		(Q24-a) Establish criteria internally for each stage	
	Z	adj. P	Z	adj. P	Z	adj. P	Z	adj. P
Non:1–2	−1.120	1.000	−2.472	<u>0.067</u>	−2.552	<u>0.054</u>	−2.611	**<u>0.045</u>**
Non:3–5	1.101	1.000	−2.117	0.171	−0.070	1.000	−0.568	1.000
Non:6–9	1.854	0.318	−0.821	1.000	−0.283	1.000	0.733	1.000
Non:over 10	0.127	1.000	−2.530	<u>0.057</u>	−1.724	0.424	−0.087	1.000
1–2 : 3–5	2.124	0.168	−0.058	1.000	2.207	0.137	1.662	0.483
1–2 : 6–9	2.437	<u>0.074</u>	0.350	1.000	0.970	1.000	2.042	0.206
1–2:over 10	0.869	1.000	−1.001	1.000	−0.082	1.000	1.655	0.490
3–5 : 6–9	1.156	1.000	0.364	1.000	−0.236	1.000	1.027	1.000
3–5:over 10	−0.690	1.000	−0.882	1.000	−1.589	0.560	0.336	1.000
6–10:over 10	−1.543	0.615	−0.940	1.000	−0.890	1.000	−0.700	1.000

The underlined number represents a p-value below the significance level of 0.1, and the bold underlined number represents a p-value below the significance level of 0.05.

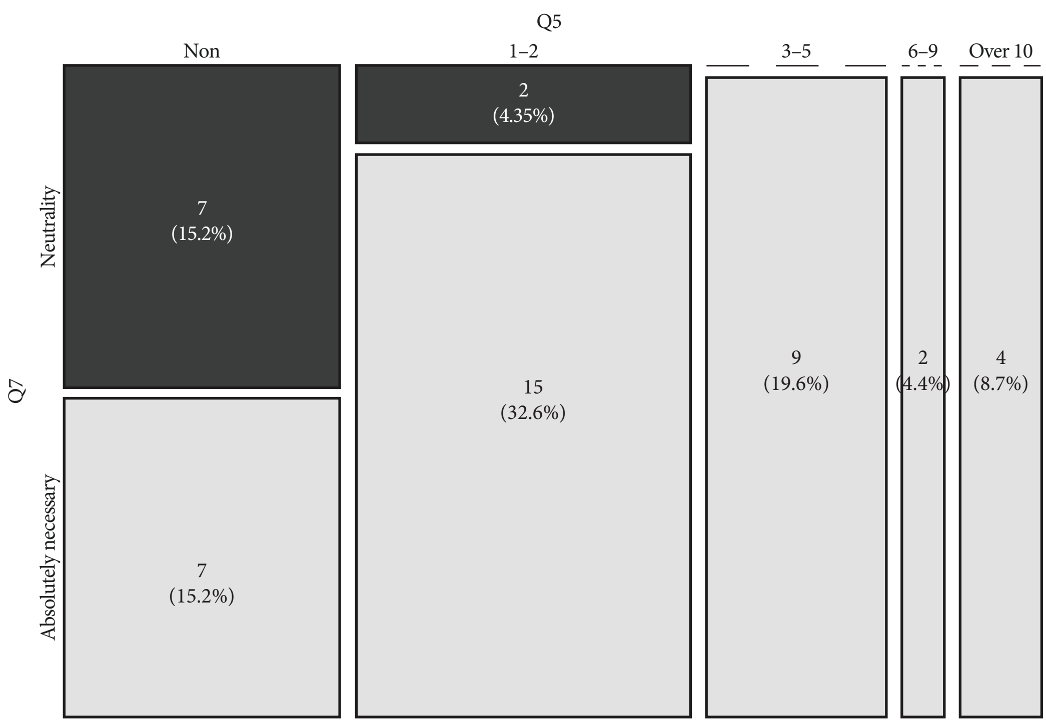

Figure 4: Survey results of Q7 and Q5.

six to nine experiences. However, the group with six to nine BIM experiences consisted of only two out of 47 respondents (4.4%), so there are limitations in interpreting the difference due to the small sample size. Furthermore, Q15-b and Q21-b revealed differences between the group with no BIM experience and the group with one to two experiences, particularly (Q15-b), which showed differences between the group with no BIM experience and the group with more than 10 experiences. Presumably, there is a difference between the group with no BIM experience and the group with any level of experience. However, since no significant differences were observed in other groups with BIM experience, obtaining a larger sample size is necessary for additional interpretation and to obtain reliable results.

4.3. Results

4.3.1. Technical Environment. In the BIM project, approximately 20% of respondents (Q7) expressed a neutral stance, while 80% (37/46) responded that the BIM room, a physical space for collaboration among participants, is absolutely necessary. Also, the Fisher exact test (Table 5) showed that the answers to Q7 were different depending on how often people participated in BIM (Q5). To see these differences, we used

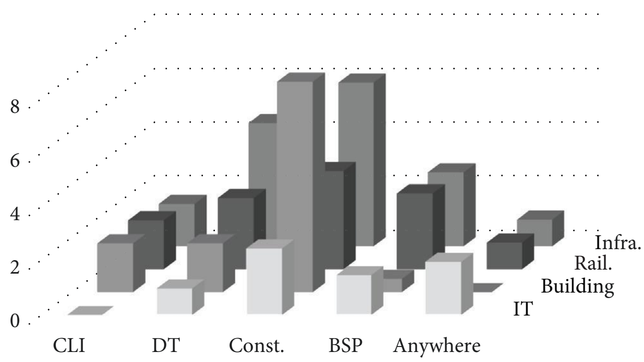

FIGURE 5: Survey results of the preferred location for the BIM room (Q9).

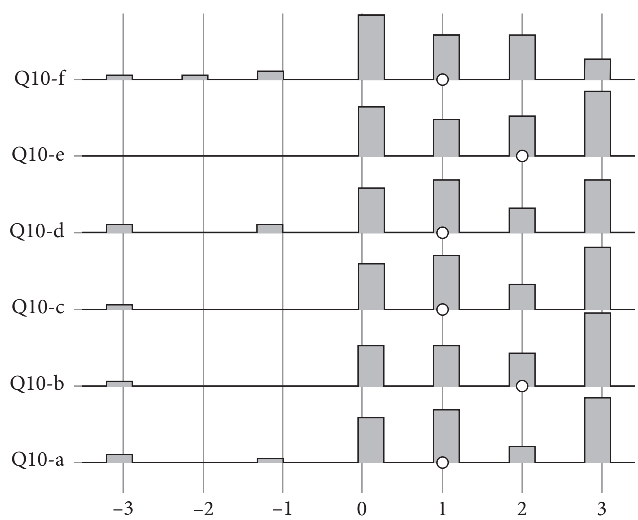

FIGURE 6: Survey results of the necessity tasks in BIM room (Q10).

the mosaic graph in Figure 4 to show the answers to Q7, broken down by how often people participated in BIM (Q5). Twenty percent of respondents who showed a neutral opinion regarding the necessity of the BIM room had either no or 1–2 instances of BIM experience, while all respondents with three or more instances of BIM experience responded that the BIM room is absolutely necessary. It can be inferred that respondents with little or no BIM experience do not perceive the need for the BIM room, whereas those with extensive BIM experience do perceive its necessity.

Regarding the capacity of the BIM room (Q8), 75% (35/47) of respondents indicated that a size of 10–20 people is appropriate, and no significant differences were found among all IVs in the Fisher's exact test (Table 5). Regardless of the field of business or BIM experience, participants in a BIM project require a BIM room that can accommodate 10–20 people.

Multiple responses belonging to two or more categories of observations in Table 2 were considered when designing the question of which organizations should be placed closest to the BIM room (Q9). The response results were aggregated in proportion to the entire response, rather than frequency. The aggregated results are presented in bar graphs classified by business areas (Figure 5). It was found that in all areas,

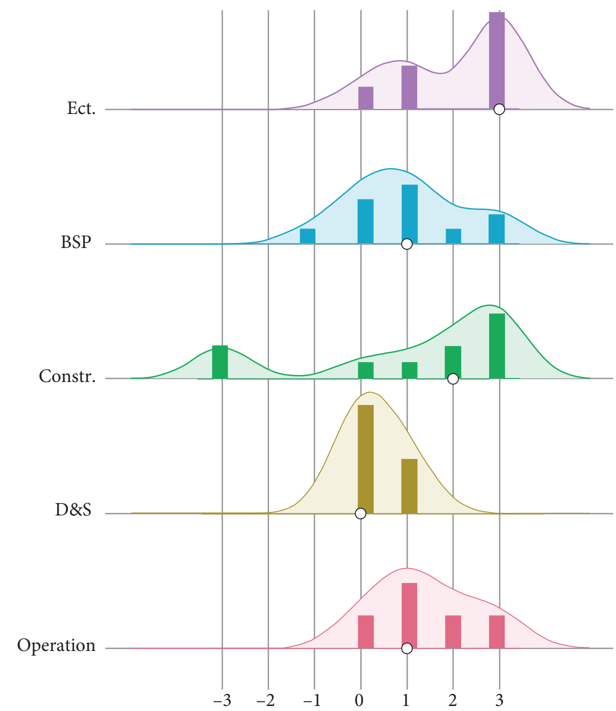

FIGURE 7: Histogram and density of Q10-a.

BIM rooms should be placed close to construction sites. Infrastructure and railways had a higher likelihood of being placed close to design teams or BSP than architecture.

Figure 6 presents the results of a survey on the necessity (Q10) of six tasks to be performed in the BIM room. The bars represent response frequencies, while the donuts indicate the median values. As the median values for Q10-a–Q10-f are located at 1 or 2, they indicate positive responses. The majority responded that design review (Q10-a), coordinating interfaces (Q10-b), quality check (Q10-c), simulation (Q10-d), preconstruction (Q10-e), and value engineering (Q10-f) should all be performed in the BIM room.

According to the Kruskal–Wallis test (Table 6) conducted to identify differences between respondent groups, no statistically significant differences were found among participants in coordinating interfaces (Q10-b), quality checks (Q10-c), and simulations (Q10-d) performed in the BIM room. However, design review (Q10-a), preconstruction (Q10-e), and value engineering (Q10-f) showed significant differences in the Kruskal–Wallis test. Therefore, this study analyzed the differences between groups using the Dunn test (Tables 8 and 9). The study also showed the histograms and density of 10-a, Q10-e, and Q10-f for each group (Figures 7–9) to visually confirm the differences found by the Dunn test through the distribution of observations.

Figure 7 shows the histogram and density function of (Q10-a), separated by expertise area (Q3). The Dunn test revealed significant differences in design review (Q10-a) between the D&S and other groups (Table 9). In Figure 8, the median for the D&S group is neutral at 0 points, while the median for the other groups is the highest at three points. Figure 8 also illustrates the disparity in data distribution

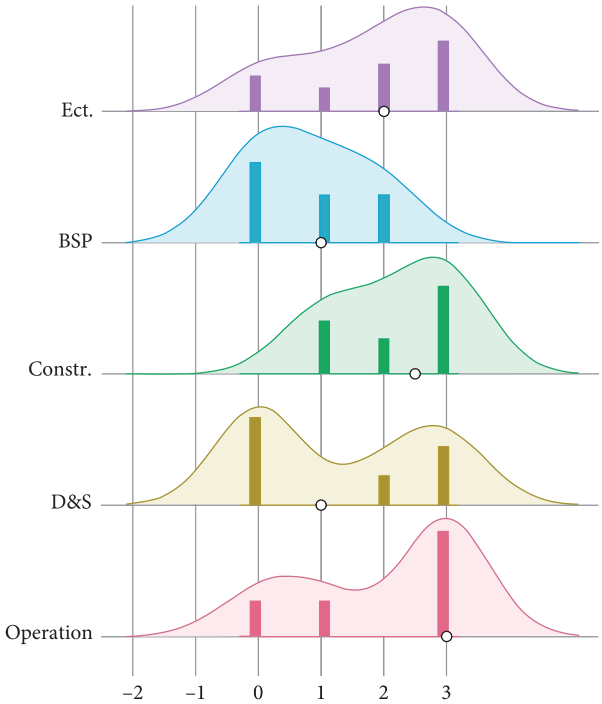

Figure 8: Histogram and density of Q10-e.

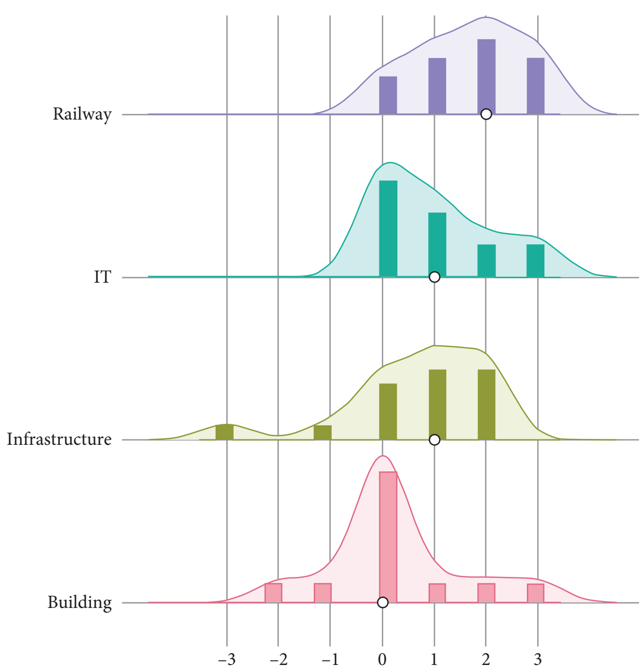

Figure 9: Histogram and density of Q10-f.

between the two groups. The ect group related IT and R&D responded that design review must be conducted in the BIM room, whereas the D&S group indicated that design review does not necessarily have to be performed in the BIM room and can be replaced by other spaces. This difference between the two groups reflects the belief that work should be carried

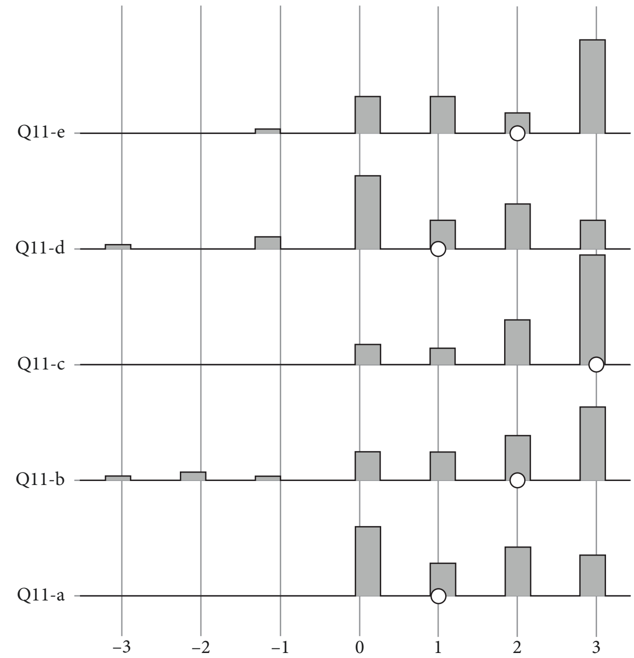

Figure 10: Survey results on the devices required for the BIM room (Q11).

out in their own dedicated space, considering that design review is one of the main tasks of the D&S group.

The Dunn test (Table 9) revealed significant differences between the contractor and BSP groups in preconstruction (Q10-e), as evidenced by the histogram and density function in Figure 8. The density function of the contractor group has its highest point and median value located between 2 and 3, while the BSP group has a median value of 1, and its highest point is between 0 and 1, which is neutral. This indicates that the BSP group does not necessarily have to perform preconstruction tasks in the BIM room compared to the contractor group. Additionally, value engineering (Q10-f) showed differences between the architect and railway groups in Table 8. In Figure 9, the median value of the architectural group was 0, which is neutral, while the median value of the railway group was closer to a strongly positive at 2. This suggests that value engineering can be performed in spaces other than the BIM room for the architectural group, whereas it must be done in the BIM room for the railway group. Considering the types and proportions of respondents in Figure 3, these differences are estimated to be the result of the high expectations of railways with relatively limited BIM experience.

When examining the median values per question in Figure 10, it is observed that the most necessary equipment for the BIM room (Q11) is a high-performance PC (Q11-c), while interactive whiteboard (Q11-a) and VR-related equipment (Q11-d) are relatively neutral compared to other devices. In particular, the use of a projector (Q11-b) is found to be more necessary than an interactive whiteboard (Q11-a), which is likely due to the widespread use of projectors in meeting spaces. Additionally, since Q11 did not reveal any significant differences in the Kruskal–Wallis test (Table 6),

Table 11: Survey results for the upcoming BIM team (Q17).

Q17	(a)	(b)	(c)	Total
Building	7	3	2	12
Infra.	9	3	3	15
Railway	3	2	7	12
IT	4	1	1	6
Total	23 (51.1%)	9 (20%)	13 (28.9%)	45 (100%)

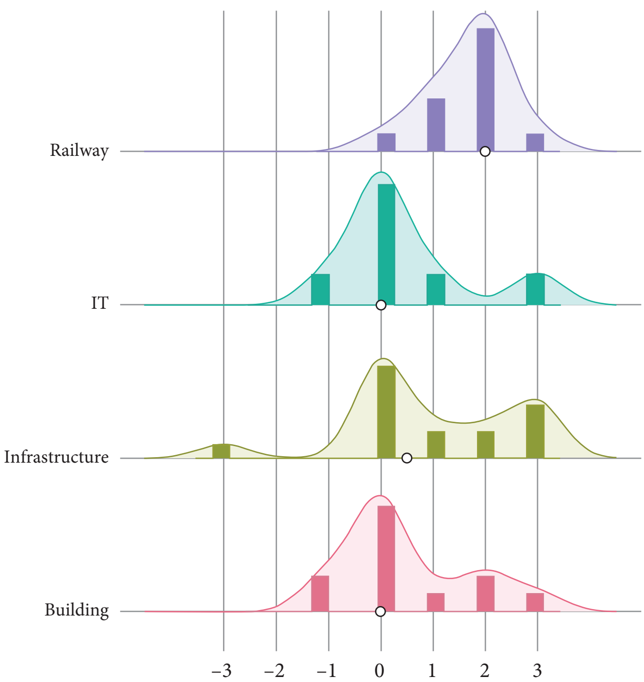

Figure 11: Histogram and density of the necessity of VR device in BIM room (Q11-d).

there were no disagreements among the respondent groups. However, relatively low *P*-values were observed in Q11-d and Q2, leading to a posttest analysis (Table 11), which revealed that architecture, infrastructure, and IT-related fields lean toward neutrality in terms of VR-related equipment (Q11-d) such as HMD and joystick, while the preference for these devices is higher among the railway group (Figure 11). The railway group's strong preference for VR-related equipment is likely due to their limited experience in implementing BIM compared to other groups, as indicated by the types and proportions of respondents in Figure 3.

During the project, it was observed that the appropriate party to provide BIM tool licenses to participants (Q12) was the client at 25.5% (12/47), the DEC or contractor at 36.2% (17/47) and the BSP at 38.3% (18/47). The survey showed that there were more opinions favoring the design firm, contractor, and BSP, who are the direct users of the BIM tool, to provide the licenses rather than the client. The participants did not disagree regarding the findings of Q12, as no significant differences were found in the Fisher's exact test in Table 5.

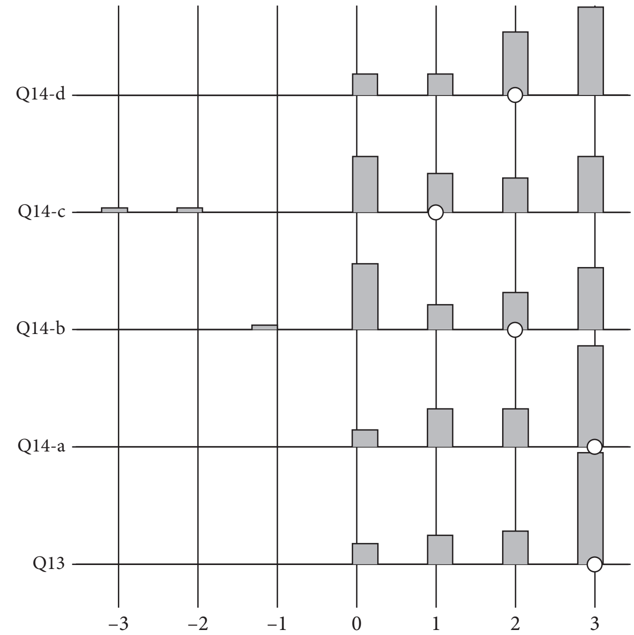

Figure 12: Survey results of the necessity of the data standards and CDE (Q13 and Q14).

All participants expressed a desire for a BIM room, and the need for a BIM room increased with more experience in BIM. Participants from all sectors preferred to have the BIM room located close to construction sites or contractors, followed by the infrastructure and railway groups who preferred it to be close to designers or BSP. Additionally, coordinating interfaces was identified as the most important task to be performed in the BIM room, with no disagreement among the participants. Participants have found that the functionality of the BIM room varies slightly depending on the business domain and their role. The design and inspection group tends to believe that design review is necessary, and the BSP group believes that preconstruction does not necessarily have to be performed in the BIM room. The railway group, with less BIM experience, responded more favorably to value engineering among the features of the BIM room. The close relationship between each task and the respective group likely explains this trend, indicating that they can be performed in a space other than a collaborative one. Additionally, the most essential equipment for the BIM room, without any disagreement among participants, is high-performance PCs. The railway group responded that they require more VR-related equipment, such as HMDs and joysticks, compared to other groups.

4.3.2. Collaborative Environment. In total, 57.4% (27/47) of respondents deemed data standards (Q13) for collaboration among various participants necessary, with no one indicating their unnecessary nature (Figure 12). Furthermore, as no *P*-value below the significance level was found in the Kruskal–Wallis test (Table 6), it can be concluded that there is a unanimous agreement among participants that standardized data definition is necessary. As shown in Figure 12, Q14 asked if the CDE platform needed cloud servers (a),

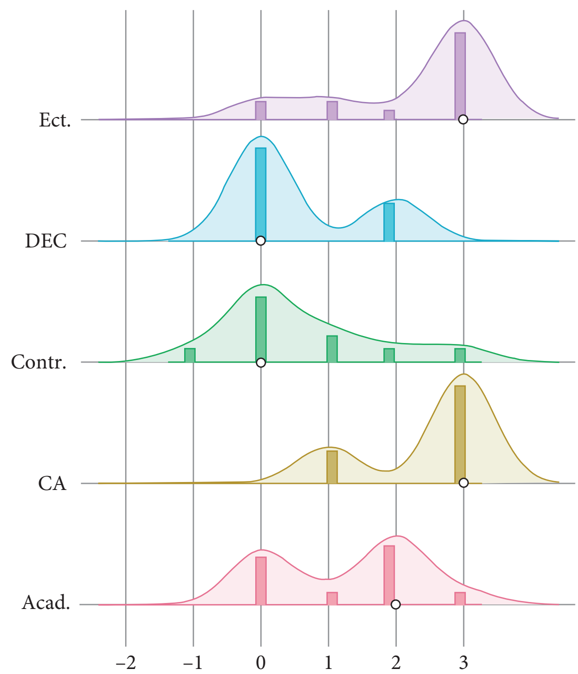

FIGURE 13: Histogram and density of the Q14-b sorted by the affiliation type.

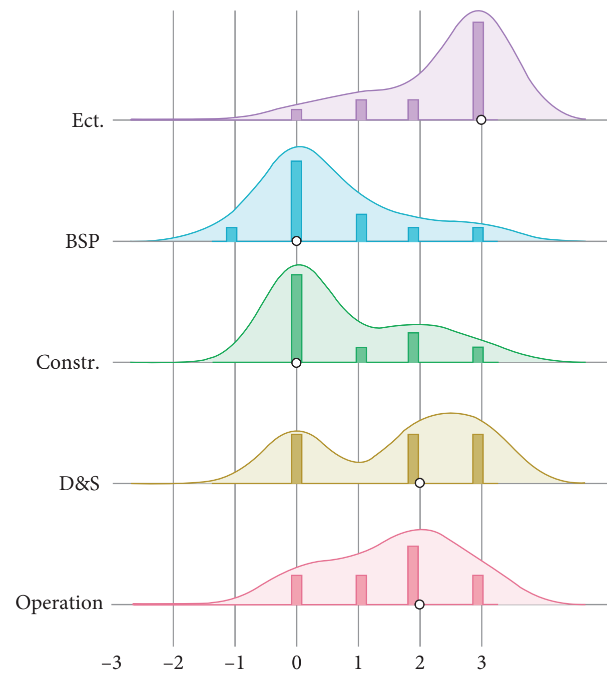

FIGURE 14: Histogram and density of the Q14-b sorted by the expertise area.

client-specific platforms (b), commercialized platforms (c), and functions that were easy for anyone to use (d). The median values for all items in Q14 were distributed between three points (positive) and one point, with Q14-a having the highest median. Since no significant differences were found in Q14-a in the Kruskal–Wallis test (Table 6), it can be concluded that a cloud server-based CDE platform is essential without any differences among participants.

However, Q14-b saw average differences in the contractor, DEC, and other groups (Table 7) and the construction, BSP, and other groups (Table 9), which were sorted by Q1 using the Dunn test. Looking at Figure 13, which visualizes the former, the median for the contractor and DEC groups is confirmed to be zero, while the median for the, Etc. group is three. In affiliation type (Q1), the other groups belong to IT related to BSP, CDE development, and in-house research and development (Research Institute) and are presumed to have responded most positively because their business area can be secured through client-specified CDE development. In Figure 13, the client group had the highest median of three points, but the test found no difference from other groups because of the low number of responses from the client group. In Figure 14, the median for the construction and BSP groups was neutral (0), while other groups showed responses close to a positive score of two or more points. Therefore, the contractor and BSP did not show a preference for client-specified CDEs compared to other participants.

In the Dunn test, there was an observed average difference in Q14-c between groups with 1–2 BIM experiences and groups with 6–10 experiences (Table 10). However, the interpretation is limited due to the small number of respondents (4.4%) with 6–10 BIM experiences. In the Dunn test, there was a significant difference in the group of Academic:Etc. for Wed, mobile-accessible CDE (Q14-d) (Table 7). The median of the academic group was lower than that of the Etc. group, indicating that the academic group perceives less need for web or mobile-accessible CDE compared to the IT group. Additionally, there were opinions in the IT field regarding the shortage of manpower for specialized platform development and the need to reflect appropriate unit prices for public projects.

Respondents identified the need for standard data definitions as the most crucial aspect of creating a collaborative environment. They also expressed the need for a cloud server-based web and mobile-accessible CDE platform. The CDE platform, which serves as the hub for information sharing and exchange among participants, received positive responses from client, R&D, and IT professionals when it came to developing client-specified solutions. However, differences in opinions were observed due to the neutral responses from contractors and BSP. Furthermore, the commercial use of CDEs garnered a positive response from all participants without significant differences or biases. Private construction projects should utilize commercialized CDEs that do not cause disagreements among participants. However, in public projects, clients can utilize CDEs developed based on their requirements. In Korea, the guidelines for establishing and operating information systems for administrative and public institutions under the Electronic Government Act prioritize the purchase of products developed by small and medium enterprises in the technical evaluation of software proposals. However, CDEs developed by small and medium enterprises should be carefully reviewed to ensure compatibility with commercialized software and interfaces and to avoid the

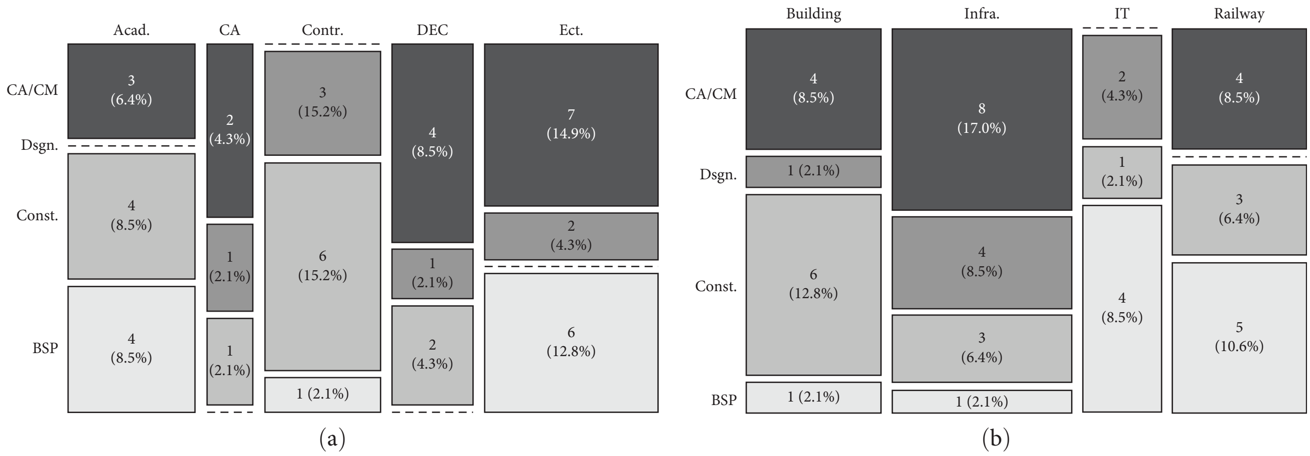

Figure 15: Survey results for the appointment of the BIM coordinator (Q19): (a) grouped by an affiliation (Q1) and (b) grouped by the business field (Q2).

need for additional efforts in data format conversion that may hinder collaboration among participants.

Q15 asked about the importance of factors needed for a collaborative environment (Q15 of Table 2): (a) arrange collaborative tasks, (b) subtask definitions, (c) coordinator appointment, (d) training coordinator, (e) defining participant's role, (f) process improvements, (g) attendance at supervisory meetings, and (h) guidance revision. The median values of all factors were positive at 2. The Dunn test revealed significant differences in Q15-b between groups without BIM experience and groups with more than 10 experiences (Table 6). However, groups with less than 10 experiences did not exhibit consistent differences, indicating the need for further observations to ensure consistent interpretation. All participants responded that the other factors were necessary for a collaborative environment without differences between groups, as *P*-values below the significance level were not observed in those factors. Participants were not clearly aware of which factors to prioritize for collaboration among the eight factors included in Q15. Participants in the BIM project responded that attendance at supervisory meetings was necessary.

4.3.3. Organization. Regarding the BIM organization (Q16) of their organization, 35.5% (16/45) of the respondents are responsible for BIM within an existing department without establishing a new team, while 37.8% (17/45) are establishing a BIM team, and 26.7% (12/45) are not assigned to a BIM division. Excluding the 11 respondents belonging to BSP, there were 11 for option (a), 12 for option (b), and 11 for option (c), which is not significantly different from the response rate of Q16. The even distribution of responses in the three types indicates that the BIM department organization is not biased. Some individuals within the organization are responsible for BIM, while in other cases, outsourcing or the establishment of a new BIM organization is preferred. Table 5 revealed a difference between the respondent's group and individuals with a relatively high level of experience (P-value = 0.1). However, this difference was not considered in the discussion due to the challenge of interpreting a direct relationship between an individual's career and the agency's BIM organization. Furthermore, the difference was not significant enough to alter the conclusion.

In Q17, half of the respondents responded that it is necessary to establish their own organization that can always collaborate to achieve the goals required by the client within the project (a). Twenty percent responded that they should entrust BSP completely (b), and 28.9% responded that they should entrust BSP temporarily and establish a BIM organization in the long-term (c). Categorizing the responses to Q17 by business area (Table 11), 60% of architecture and infrastructure chose to establish a collaborative organization (a), while 60% of railroads chose to temporarily entrust BSP and establish an organization in the long-term (c). Although there is no statistically significant difference between the *P*-values of Q17 and Q2 in Fisher's test in Table 5 (0.324), there is a difference in the number of responses between groups in Table 11, excluding the IT group. Railway groups with relatively little BIM experience tend to prefer temporary commissions to BSP and the formation of a long-term BIM organization, while architecture and infrastructure do not.

In Q18, approximately 64% of respondents indicated that a full-time BIM coordinator was necessary, while 32% remained neutral and 4.4% responded that it was not necessary. The respondents who stated it was not necessary, 4.4%, were found to be working in the IT and railway sectors, and there were no observations of responses indicating that a coordinator was not needed in the architecture and infrastructure sectors. In Q19, it was found that 34% (16/47) considered it appropriate to assign the BIM coordinator to the client and construction project managers, 27.7% (13/47) to the contractor, 23.4% (11/47) to the BSP, and 14.9% (7/47) to the designers. Furthermore, the significant differences observed in the group based on affiliation (Q1) and business area (Q2) in Table 5 led to the visualization of the results of Q19, distinguished by Q1 and Q2, as a mosaic plot in Figure 15. In Figure 15(a), it can be observed that contractors differ in their responses, stating that the BIM coordinator should be assigned to designers, contractors, and BSP, while other groups should be assigned to clients, CMs, and contractors. As shown in Figure 15(b), in the groups separated by business sector (Q2), there was a high response indicating that the BIM coordinator should be allocated to contractors for the construction sector and that the BIM coordinator should be allocated to designers compared to other sectors. For railways, respondents indicated a higher preference for allocating the BIM coordinator to BSP rather than architecture and infrastructure, aligning with the tendency to temporarily commission BSP due to limited BIM experience, as confirmed in Table 11.

Currently, participants have expressed a desire for a dedicated BIM team with a full-time coordinator assigned within the project for ongoing collaboration, which has been implemented in a balanced manner through establishing a new division, assigning it to an existing division, or through outsourcing. Although the builder had reservations about the coordinator being assigned to clients and construction project managers, other participants preferred the coordinator to be assigned to them. Projects that have coordinators assigned to builders require an alternative where clients and construction project managers attend BIM meetings to facilitate smooth communication among all participants except the builders. In terms of business type, there was a tendency for infrastructure projects to prefer designers, while railways showed a preference for assigning coordinators to BSP. Although not statistically significant, the railroad group showed an inclination to temporarily delegate the appointment of coordinators and the configuration of the BIM team to BSP. On the other hand, the infrastructure and building groups responded that designers and builders should take the lead in organizing the teams rather than relying on BSPs. Railways with relatively little BIM experience should examine why participants in BIM-experienced buildings and infrastructure believe that contractors and clients should take the lead in organizing rather than relying on outsourcing and incorporate this into their strategies for BIM implementation.

4.3.4. Execution Guide. Of the respondents to question 20 (Q20) regarding whether a minimum definition of organization, work, and role should be included in the revised guidelines, 44.4% (20/45) answered in favor of inclusion, while 46.7% (21/45) suggested including it in the statement of work. Additionally, 9% (4/45) stated that it is still too early to regulate it in the guidelines. Participants wanted the organization and role to be defined in the guidelines or task directives.

Q21 asked whether three definitions of (a) organization and roles, (b) subtasks and procedures, and (c) criteria for competency evaluation should be included in the guidelines for constant collaboration. Figure 16, which displays the results, indicates that both the median values and bars of the three definitions were strongly positive. Therefore, the directive must include all three definitions. Q21-b found a relatively significant difference by Dunn test between a group without BIM experience and a group with one or two sessions. Figure 17 shows the histogram and density of Q21-b grouped by BIM experience. The group without BIM experience showed a data distribution ranging from neutral (0) to strongly positive (3), while the groups with one to two BIM experiences and 10 or more BIM experiences showed a distribution close to strongly positive (3) and a median value. Participants with BIM experience responded that subtasks and procedure definitions were needed. However, participants with 6–10 BIM experiences, despite the density function being printed the same as the *X*-axis due to the limited number of samples, will be able to observe group differences based on BIM experience with more samples.

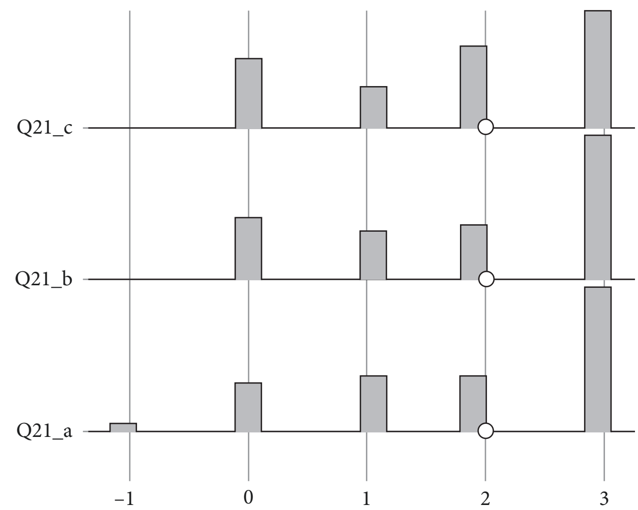

Figure 16: Survey results of Q21.

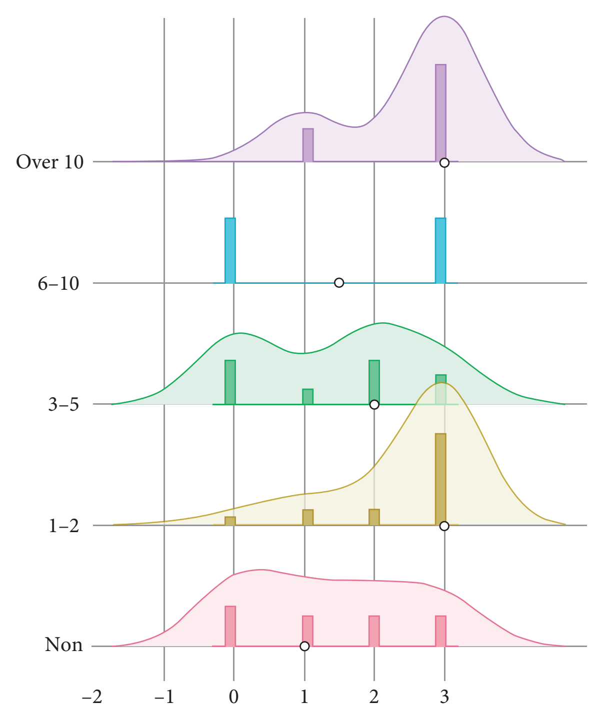

Figure 17: Histogram and density of Q21-b.

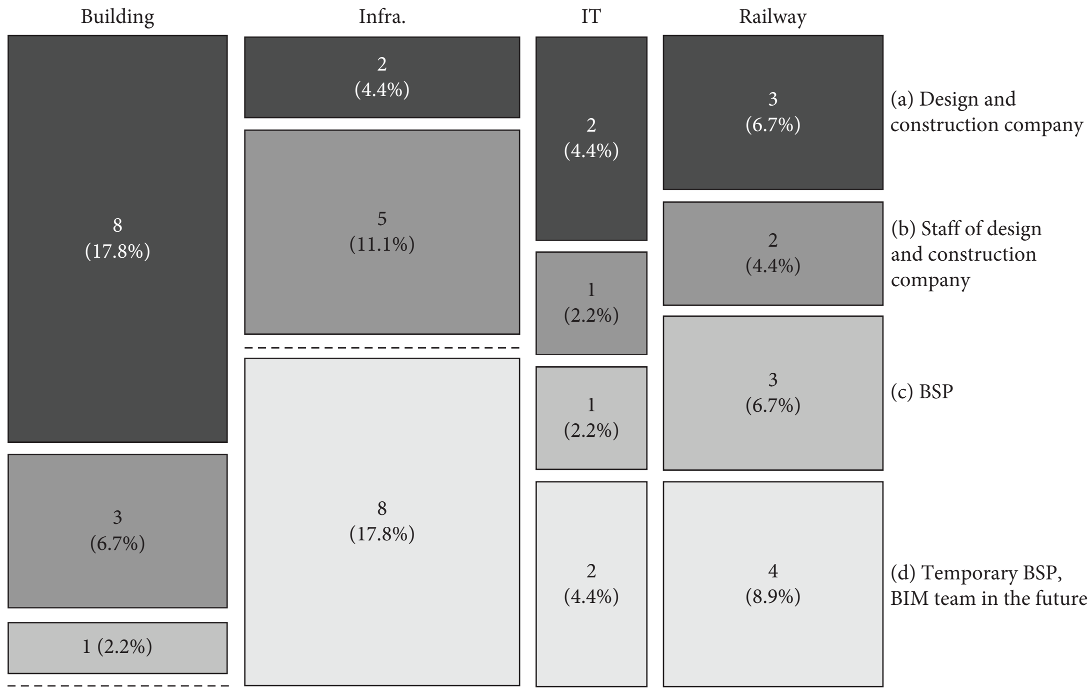

FIGURE 18: Survey result of the BIM competency assessment subject (Q22).

4.3.5. Evaluation. In the survey, the appraisees who needed to review their past performance for BIM competency evaluation prior to the task were identified (Q22). In the survey, evaluators who needed to review past performance for BIM competency assessment prior to work (Q22) were identified. Designers and contractors (a) should be evaluated by 33% of the respondents (15/45), while 24% (11/45) mentioned that the previous experience of BIM managers and collaborators within the designers and contractors should be evaluated (b). Additionally, 11% (5/45) considered evaluating the past performance of the BSP (c), and 31% (14/45) responded that the past performance (d) of the BSP and future BIM team should be evaluated temporarily. Since there were significant differences between the business area (Q2) and Q22 in Table 5, the mosaic graph confirmed this, as shown in Figure 18. Respondents in the architecture field recommended evaluating designers and contractors, while those in the infrastructure field suggested temporarily evaluating the BSP and future BIM team. The railway sector showed an even distribution of responses from (a) to (d), along with IT. In the architecture field, which has been applying BIM for a relatively long period, the response indicated a need for evaluating the capacity of designers and contractors rather than the capacity of their employees. There was no response regarding the capacity assessment of the BSP. In the field of infrastructure, no one responded to the evaluation of the BSP, and half responded to temporarily evaluating the BSP and evaluating future BIM teams.

The need for evaluation after execution is completed can be determined from the responses to Q23, which can be seen on the bottom X-axis of Figure 19. The median value of Q23 is 1, and since most responses are distributed above 0, an evaluation of BIM execution is necessary after the task is completed. Additionally, Figure 20, which visualizes the responses of Q23 with density functions and histograms, shows that the BSP group is closer to neutral while the other group is very positive. The BSP group, unlike the other group, is the most concerned group selected for evaluating BIM performance. Q24 asked about the need for five processes and criteria for evaluation, which are as follows: (a) establishing internal BIM evaluation standards and conducting self-evaluation for each stage, (b) ensuring fairness and

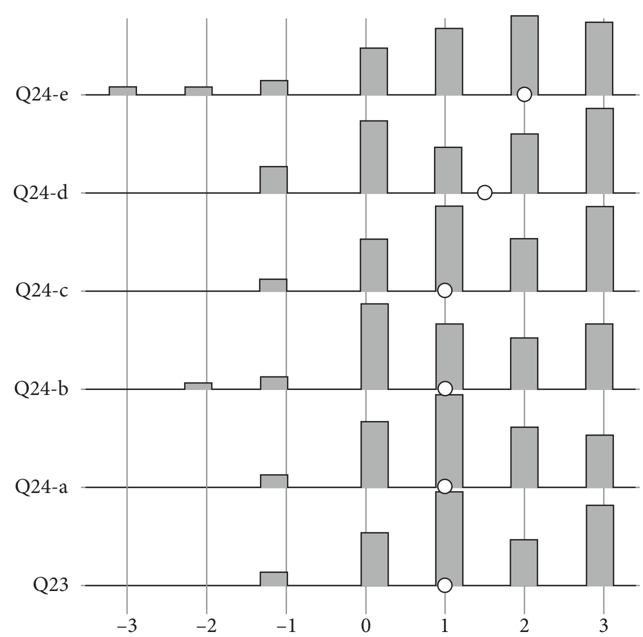

FIGURE 19: Survey results of Q23 and Q24.

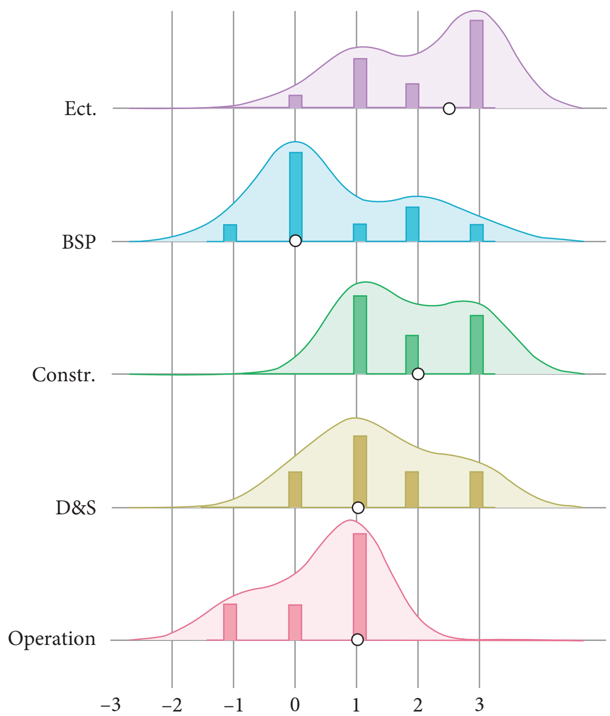

Figure 20: Histogram and density of Q23.

objectivity by forming a professional internal and external evaluation committee, (c) quantitative evaluation of BIM performance, including the level of achievement, (d) qualitative assessment of BIM application effects and participant satisfaction, and (e) awarding additional points based on the owner's requirements and the level of utilized BIM. Figure 19 displays the response results for Q24. Responses from (a) to (c) in Q24 were close to neutral with a slightly positive inclination. However, there was a relatively higher positive response to qualitative evaluation (d) and the allocation of additional points (e) based on the owner's requirements and the level of implemented BIM. In Table 10, Q24-a found a significant difference between the group with no BIM experience and the group with 1–2 experiences. However, the median of the group with no experience was 1, while the median of the group with 1–2 experiences was 2. Therefore, this difference does not have a significant impact on the interpretation. However, participants with BIM experience responded that there is a need for internal evaluation criteria, indicating their awareness of the common need for such criteria and the potential for improved work efficiency and capabilities if established.

Architectural, railway, and infrastructure participants all recognized the need for evaluation and evaluation criteria after the completion of the task. However, their responses regarding the subjects to be evaluated varied. Many architectural groups responded that they should evaluate the past performance of the design and construction company, while no one responded regarding BSP's performance. The majority opinion for infrastructure was to evaluate BSP temporarily and the future past performance of the BIM Team. Railroads with relatively little BIM experience did not show significant differences between response types. Evaluating only the capabilities of the BSP after the task is completed is not sufficient. The experience of the BIM team or the designer and contractor should be considered in the evaluation. Particularly in architecture, there were more opinions that emphasized evaluating the company's capabilities rather than the BIM manager and coordinator. This indicates that the company's willingness and efforts are crucial for BIM implementation and that the company's relevant resources are more important than individual capabilities. Since the architectural group BIM has been applied in Korea, it is necessary to consider the trend of the architectural group. Furthermore, to secure unanimous agreement from all participants, it is advisable to assign extra points based on qualitative evaluation, the owner's requirements, and the complexity of BIM application technology, considering that BSP exhibited a neutral response compared to other participants. This is because this method ensures an unobserved response among participants.

The appraisees for BIM competency evaluation displayed varying responses across architecture, railway, and infrastructure sectors. Most responses in architecture indicated a need to evaluate the company's past performance in design and construction, while BSP's evaluation received no response. In infrastructure, the majority favored evaluating BSP in the short term and expanding the evaluator pool by evaluating the BIM team in the long term. There were no significant differences observed among response types in the railway sector, which has relatively less BIM experience. In summary, it is essential to reflect not only BSP's capabilities but also the BIM Team's, design firms, and construction companies' experiences in the competency evaluation. Regarding architecture in particular, opinions suggest that evaluating the company's capabilities is more essential than assessing the BIM manager and coordinator. This emphasizes the importance of the company's willingness and effort in applying BIM, as well as having ample related resources. Although BIM application may vary across projects depending on the business area, the opinions of the architecture sector, which has been applying BIM for a relatively longer period, need to be considered. Furthermore, BSP finds BIM execution evaluation more burdensome than other groups, despite all participants acknowledging its necessity after task completion. To facilitate quick consensus among participants, the evaluation should be designed with bonus points and qualitative assessment considering the client's requirements and the level of utilized BIM.

5. Discussion

The findings of this study reveal the preferences of Korean AEC participants in BIM projects regarding collaborative environments, technical environments, organizational structures, execution guidelines, and evaluations. To meet the technical requirements, physical collaboration spaces aimed at coordinating interfaces need to be established, with a capacity to accommodate 10–20 individuals. The placement of the BIM room was preferred to be close to the construction team for all architecture, infrastructure, and railway groups. However, due to the relatively high preference of the design team for infrastructure and railways for BSP, there were differences in the preferred location based on the application period and organizational structure. While the primary function of the BIM room is to coordinate interfaces, there were slight variations based on the participants' roles. Participants from the design and inspection group, which is directly involved in design review, expressed a neutral stance on whether preconstruction should be performed in the collaborative space. Although the specific equipment may vary depending on the project's technology utilization, there was a consistent demand for high-performance PCs among participants, without any disagreements.

Compared to previous studies that emphasize the significance of the technical environment, our research findings offer comprehensive information about the technical environment according to the type of business [3, 11, 28]. They can be used to provide standards for assessing BEP as well as BIM performance. Technically speaking, for instance, it can be determined whether the BIM room can hold 10–20 people for interface modifications, if it is furnished with high-performance computers, if it is situated next to contractors in building projects, if it is next to design teams or contractors in infrastructure projects, if it is next to BSP or contractors in railway projects, and if it has high-performance computers or comparable equipment. Performance reviews and BEP reviews might be based on these standards.

In a collaborative environment, standardized data should be defined, and a commercialized CDE is necessary for all participants [19, 48]. Client-specified CDE usage has received positive responses from clients, R&D professionals, and IT professionals, but since the contractor and BSP have shown a neutral response, there is a risk of disagreements among participants. As all participants prefer cloud servers, measures should be in place for data backup, leakage, and security related to the use of cloud servers [21, 45, 51]. Korean public institutions, which are required to comply with laws regarding the preferential purchase of products developed by small and medium-sized enterprises in relation to the establishment and operation of information systems, should select a CDE that has ensured mutual compatibility and completed interface review without requiring additional efforts in collaboration with participants.

Above all, the results show that most of the tasks related to collaboration are important. However, Korean AEC participants have not yet recognized which tasks should be prioritized for collaboration. It is unclear to the participants which factors are urgently needed for collaboration and which factors should be reviewed first. For effective BIM goals and performance management, clients and project managers need to ensure smooth collaboration [65]. Currently, smooth collaboration is difficult, so participants are demanding attendance at meetings between clients and project managers. Based on the eight tasks (Q15) mentioned in this survey, BEP should provide ways to prioritize tasks related to collaboration to enhance the level of collaboration.

On the other hand, in the field of architecture, constructors prefer to take the lead in forming a team and evaluating both the constructor and the designer, rather than relying on BSP. Railways preferred to delegate the appointment of a BIM coordinator to BSP, while construction companies were preferred in the case of architecture. However, there were also differences among participants who were not construction companies, based on their roles as participants who preferred client and project manager. Therefore, even if the coordinator is assigned to BSP or a construction company, it is recommended that the client and project manager attend BIM meetings for a smooth collaboration environment. Additionally, railway projects should reflect the tendency of architectural groups to have a higher level of utilization than railways, based on the correlation that higher BIM experience leads to higher utilization levels.

Each participant acknowledges the need for evaluations following BIM execution, and they favor qualitative evaluations that take the needs of the client and the level of use into account. Previous evaluation studies have advised combining quantitative and qualitative assessments [36, 40, 57]. Participants' resistance to evaluations can be lessened by increasing the proportion of qualitative assessments, since they view them as beneficial. Furthermore, participants still prefer guidelines or task instructions to define minimal organization and roles, especially those with BIM experience who want subtasks and procedures to be included. Each building, infrastructure, and railway group exhibited different tendencies in terms of the subjects to be evaluated. Most respondents stated that construction should evaluate designers and contractors, and many expressed the opinion that BSP should evaluate the BIM team in the long term, and railways should evaluate BSP compared to other groups.

There were differences observed in groups based on participant roles and facility types for details like the deployment of the BIM room, data standards for collaboration environments, composition of the BIM team, and evaluation targets in the technical environment, even though participants did not perceive the collaborative environment, technical environment, organizational composition, execution guides, and the need for evaluation differently. Groups differed in how the BIM coordinator was allocated according to participant roles and facility types. Additionally, there were discernible disparities between the groups based on participant roles when it came to client-specified CDEs. Divergent perspectives among the participating organizations can pose a communication obstacle during the project; therefore, it is imperative to make strategic modifications to the BIM execution process to preemptively remove these barriers. This is so that constructive leadership can increase the productivity of BIM projects, and constructive leadership requires the ability to communicate [66].

Clients should attend regular meetings in addition to designating a BIM coordinator so that the implementation approach can be adjusted to account for the low degree of engagement [3, 67]. Furthermore, by creating data standards, assembling BIM teams, and conducting appropriate assessments, various teams or institutions that are in charge of ordering public projects for various facilities might create distinct approaches. For instance, in the case of a railway project with little experience with BIM application, it is advised to recommend data standards that are compatible with the operation and maintenance system of the ordering agency, build a BSP-oriented BIM team as soon as possible, and qualitatively assess the team's performance. However, it is advised to build BIM teams around construction businesses and assess the performance of designers and construction companies for construction projects with a history of considerable BIM application. By proactively addressing barriers to potential communication and cooperation brought on by disparities in participant views, differentiated implementation strategies facilitate smooth collaboration and make it possible to accomplish project objectives.

6. Conclusion

This study investigated what AEC participants wanted and what they thought were the different aspects of the technical environment, organizational structure, execution guidelines, and evaluation that needed to be discussed before BIM could be used. The survey results revealed that participants' viewpoints did not exhibit substantial variations in the domains of architecture, infrastructure, and railways. However, it has been disclosed that strategic variations are essential for determining the positioning of space for meetings within the technical environment, establishing data standards for the collaborative environment, forming BIM teams, and establishing evaluation criteria based on facility types. The distribution of BIM coordinators, which varied among groups categorized by facility types and participants' roles, has the potential to contribute to conflicts among participants. Hence, to facilitate seamless cooperation, it is advisable for participants to implement supplementary measures, such as mandating the attendance of both client and project managers in BIM meetings. In addition, if using a commercialized CDE specifically designed for clients is not feasible due to governance concerns, it is necessary to prepare by ensuring compatibility and reviewing interfaces. There may be expected resistance from some participants. This study found perception gaps that can be missed in the BEP establishment process by examining the empirical state of stakeholders' understanding of BIM implementation. It also noted elements that can make communication more difficult as a result of these disparities in perception. This study also covered implementation techniques and cooperation to proactively overcome these obstacles.

This study confirmed that the greater the number of BIM project participations, the greater the BIM usage level identified by users, resulting in ongoing enhancement of participants' utilization levels. The level of BIM utilization by stakeholders is increased by continuous orders for BIM projects. Additionally, the chances of successfully applying BIM are increased by developing an effective BIM application environment through implementation strategies that consider the varying perspectives of stakeholders and help to enhance stakeholders' capabilities through continuous orders. Sub-BIM guidelines appropriate for the customer's business area can be developed by leveraging differences in participant perceptions by type of facility. The 47 respondents, however, cannot be said to be representative of the Korean construction sector; therefore, the survey's conclusions could differ based on the subjective judgments of its users. There may be restrictions related to geography and culture on the data gathered and examined in the Korean context. The small sample size of this study and the restrictions on multiple analyses based on variable combinations may have led to data bias. Because there were so few respondents with 6–10 instances of BIM experience, it was particularly difficult to discover statistically significant differences in the analysis related to BIM experience in this survey. Nevertheless, by modifying BIM execution techniques that represent participants' perceptions from surveys and tests created with multiple factors, this study is significant in that it offers an environment for attaining developmental governance and successful BIM examples.

This study took common or conflicting views from AEC participants and used them to glean insights about the BIM deployment strategy in the construction industry. After the suggested strategic improvements are put into practice, more research can be done to track how participants' awareness and collaboration have changed because of their cumulative BIM experience. This survey can be used as a tool to evaluate the BIM strategy's suitability. Furthermore, because participant perceptions can differ based on cultural and regional contexts, conducting additional surveys in other contexts that are representative of this study can benefit comparative research on BIM implementation as well as the diversification of BIM execution strategies. Regression analysis and other multivariate analyses might be carried out more reliably if some nominal characteristics—like BIM experience—were transformed into quantitative variables and a bigger sample size was attained. In addition to BIM, this research can be used to survey users' opinions about the introduction of new technology like artificial intelligence. It can also be broadened to include research on sustainable BIM execution and performance measurement based on an optimal BIM collaborative environment.

Abbreviations

CA: Contracting agency
DEC: Design and Engineering Company
BSP: BIM service provider
D&S: Design and supervision.

Data Availability

The survey data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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