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An analysis of BIM jobs and competencies based on the use of terms in the industry

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ABSTRACT

The emergence of building information modeling (BIM) has generated several BIM jobs. However, despite opinions by BIM experts, questions regarding BIM jobs and their competencies still have no clear solution. This paper addresses this question by the collection and analysis of 242 online job postings, written in English, from the US, the UK, and China. These 242 job postings comprised a total of 32,495 words, from which 35 types of job titles and 5,998 terms related to job competency were extracted. Sequentially, the 35 job types were classified into eight BIM job types by analyzing the relations between the job titles using the role and position analysis of social network analysis. The eight BIM job types were BIM project manager, director, BIM manager, BIM coordinator, BIM designer, senior architect, BIM mechanical, electrical, and plumbing (MEP) coordinator, and BIM technician. The 5,998 competency-related terms were categorized into 43 competency elements using the O*NET classification as a framework for analysis. The 43 competencies were then subcategorized into essential, common, and job-specific competencies for the eight BIM job types. The findings of this paper could contribute to the research, industry, and academia by a) providing researchers with a scientific foundation for conducting studies related to BIM jobs and competence in the future; b) setting up guidelines for recruiting and training BIM experts in the industry; and c) allowing universities to develop BIM-related courses depending on their educational goals.

1. Introduction

The number of projects that mandate building information modeling (BIM) has rapidly increased throughout the world, which in turn has increased the demand for skilled BIM professionals. The “Markets and Markets” 2015 report [18] predicted that the BIM software and service market will reach a value of 7946.5 million dollars by 2020 at a compound annual growth rate of 13% between 2015 and 2020. Given the 3.5% global construction market growth rate [25], this 13% growth rate in the BIM market is an extraordinary number. However, the rapid growth of the BIM market has led to a dearth of prepared and skilled BIM personnel in the industry. Several studies have pointed to the lack of skilled BIM personnel as one of the major obstacles limiting the implementation of BIM in practice [8,32].

When educating and hiring BIM personnel, some of the first questions involve distinguishing between the differences in BIM jobs, such as BIM managers and BIM coordinators, and determining the required competencies. For example, Taiebat and Ku [28] argued that a lack of clear definitions and qualifications for BIM jobs leads to confusion in both academia and industry. From a pedagogical point of view, the challenge is to establish an effective education program when clear definitions and qualifications for BIM jobs remain are lacking. From an industry point of view, the hiring and evaluation of BIM-related personnel are major challenges.

Several studies have been conducted to define BIM jobs and competencies. For example, Succar, et al. [27], Barison and Santos [4], and Abdulkader [1] analyzed the changes in BIM jobs. However, they did not directly address the following questions:

- What are the current types of BIM jobs in the industry?
- What are the competencies required for each BIM job?

The aim of this study was to provide answers to these questions by analyzing BIM jobs and the competencies required by the industry. We sought these answers by collecting and analyzing 242 BIM-related online job postings from the US, the UK, and China using social network analysis (SNA) and statistical analysis. This paper is composed of six sections. Following this introductory section is a second section that provides an in-depth review of the existing classifications for competencies and previous studies on BIM competencies. The third section

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describes the research scope and method. The fourth section reports the results of the analyses of BIM jobs and their competencies. The fifth section presents the implications of the analysis results and their application to BIM education, training, and employment. Finally, the Conclusions and discussion section summarizes the conclusions of this work and discusses the contributions, limitations, and future research directions.

2. Literature review

This section presents a review of relevant studies in two subsections. The first subsection reviews the concepts and classifications of competencies and provides definitions of the terms used in this study. The second subsection reviews previous studies on competencies for BIM-related jobs.

2.1. Concepts and classifications for competencies

The term “competency” is derived from the Latin word “competens” [20], which means “an ability of an individual to be successful in their job or a standard to select the best candidates from the average or below average person or a guideline to develop the organizational performance [27].” Although various definitions exist [16], “competency” is generally defined as a combination of knowledge, skills, and abilities (KSA) and other characteristics needed to perform a specific task (or KSAOs, including other characteristics) [26]. The KSA framework for classifying different types of competencies is the most commonly used throughout the world. For example, the Human Resource Development Service Korea (HRDKorea) developed national competency standards based on the KSA framework [13]. The United States Department of Veterans Affairs (USDVA) also uses the KSA framework to distinguish “qualified candidates” from “unqualified candidates” for a position [30]. The Occupational Information Network (O*NET)—the job and competency classification used by the US government—is also based on the KSA framework.

The O*NET content model consists of two groups and six subgroups (Fig. 1) [31]. The first group is referred to as the “characteristic” group, which is a group of competency elements that are susceptible to social needs, such as abilities. The second group is referred to as the “requirement” group, which is a group of job-focused unique competency elements, such as knowledge and skills. The two groups are further classified into the following six subgroups: 1) Worker characteristics are personal traits that involve approaches to tasks and the acquirement of work-related knowledge and skills, including occupational interests, work values, and work styles; 2) Unlike worker characteristics, worker requirements are defined by the O*NET content model as developed or acquired knowledge, skills, and education through work-related experience; 3) Experience requirements refer to previous work activities in an occupational group in the past, such as related work experience or licenses that demonstrate a worker's experience; 4) Occupational requirements are typical activities across occupations; 5) Workforce characteristics are social and economic structures that might be influenced by occupational requirements; and 6) Occupation-specific requirements are a set of general information items for describing a job, such as job titles, tasks, tools and technology, whereas the other five groups are cross-occupational. Thus, in Fig. 1, only the occupation-specific requirements are boxed with a dotted line to distinguish them from the others.

The O*NET content model has two advantages. First, the O*NET content model was developed using a job and organizational analysis with a considerably large amount of data [3], and it was already used to identify over 1110 job titles. This content model shows information required for jobs as a hierarchical structure, which aids easy understanding [15]. Second, O*NET was developed based on several existing models: a functional job analysis (FJA), the position analysis questionnaire (PAQ), the emploi-type etudié dans sa dynamique (ETED), and developing a curriculum (DACUM). The FJA conducts a job analysis in a quantitative manner and assumes the existence of three types of worker functions (i.e., data, people, and things) that describe each job [24]. Compared to the FJA, the PAQ is much more quantitative and uses a five-point scale, which determines the degree to which 194 different task elements are involved in performing a particular job [19].

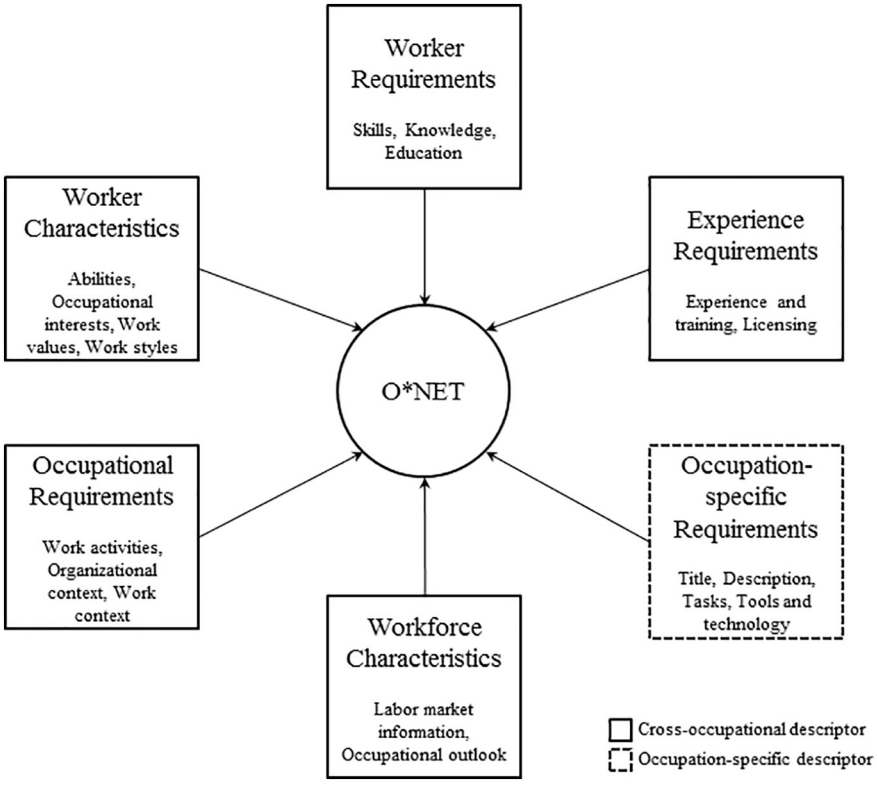


Fig. 1. O*NET content model [21].

Unlike the PAQ survey, the ETED is conducted as a sociological analysis that examines the relationship between activities of the jobholder and job family [20]. DACUM derives the core competencies of each subject professional group using a pervasive job analysis method (a job-oriented task analysis method).

For these reasons, O*NET was used in this study as a framework for analyzing BIM competencies. Various job-related terms of competencies are used interchangeably in occupational studies. This paper used the terms jobs and competencies according to the following descriptions:

- Job: In general, the term "job" focuses on what activities are performed. Broadly speaking, "job" is synonymous with "role." However, a gap exists between the two terms. A role is "a pattern of expected behaviors, which is not necessarily defined regarding specific job tasks" [29], while a job is a final set of tasks involving detailed work activities that should be measurable in objective and verifiable ways [21]. For this paper, the term "job" was selected and used to define BIM competencies. A clear definition of a specific job requires three elements [31]. The first requirement is a job title, because a job title provides the details of individual duties in a few words. Second, alternative job titles may be provided to define a job's boundaries. Third, job-specific tasks are required to describe the essential functions of the job. The meaning of essential functions is closer to the desired results rather than to the mandated performance [19].
- Competency: Derived from the Latin word "competens," the term "competence" is usually defined as "an individual's ability to perform a specific task or deliver a measurable outcome [27]." For this paper, BIM competency is defined as the set of requirements for BIM-related jobholders or candidates that allows appropriate performance of their BIM job. Competency consists of skills, knowledge, educational background, experience, and licenses.

2.2. Previous studies on BIM professional competencies

Recent BIM-related publications, including the US National Building Information Modeling Standards (NBIMS), have highlighted the importance of collaboration in a project [9]. However, in BIM education facilities or training centers, the prevailing perception is still that BIM software skills are much more important for conducting BIM well than are other aspects of BIM competencies, such as collaboration and coordination skills. A survey of the BIM education track for undergraduate students and employees of the BIM industry performed by Wu and Issa [32] indicated that the respondents perceived BIM software application skills to be the most important learning outcomes of BIM education programs, followed by knowledge of BIM concepts and literature, understanding BIM standards and interoperability issues, BIM internship and work experience, and network-based BIM model management knowledge. Along the same line, a survey by Zuppa, et al. [33] showed a pervasive perception in the architecture, engineering, and construction (AEC) industry that BIM was a tool for visualization and coordination that helped to avoid the errors and omissions.

On the other hand, quite a few studies have identified types of competencies other than software skills as core competencies for BIM professionals. An analysis of 31 online BIM-related job advertisements in the US by Barison and Santos [4] classified BIM jobs into eight types. The eight types of BIM jobs were BIM manager, BIM modeler, BIM trainer, BIM director, BIM technician, BIM consultant, BIM marketing manager, and BIM software support engineer. However, since most of the collected jobs (70% of the samples, 22 cases) were BIM manager positions, and only two cases of other job types were considered in their paper, they focused on the BIM manager and analyzed six competencies for BIM managers: aptitude, education, experience, skill and ability, knowledge, and attitude [4]. Barison and Santos concluded that the competencies required for a BIM manager include the ability to work with a computer, a Bachelor of Science degree in AEC, industrial experience from 3 to 7 years, oral and written communication skills, presentation skills, systemic and critical thinking, teamwork, programming language skills, and interpersonal skills; however, the sample size of this study was too small to draw any statistically meaningful conclusion. Naturally, the research method was exploratory rather than descriptive.

Several other studies also proposed a classification for BIM jobs. For instance, Joseph [14] classified BIM jobs into seven types based on his experience: BIM managing director, BIM manager, BIM job captain (model manager), BIM coordinator, BIM technician, and BIM application specialist I and II. Abdulkader [1] also proposed eight types of BIM jobs based on his observations: BIM manager, BIM modeler, BIM analyst, BIM application developer (BIM software developer), BIM modeling specialist, BIM facilitator, BIM consultant, and BIM researcher. Nevertheless, these classifications were all developed based on observations or experience, without a sound theoretical foundation.

In addition to recent research that has revealed BIM job types and competencies, Succar et al. [27] proposed the only competency framework for BIM through a job advertisement analysis using taxonomy-based clustering. This framework classified competency into three groups—core competency, domain competency, and execution competency—and matched each group. According to this framework, for example, when a core competency group shows creativity, the core activity is related to the activity of design conceptualization in a domain competency, and the operation skill of the "ArchiCAD" software is related to the execution competency group. This study showed the ways to acquire, apply, and access BIM competency in an understandable way, however, there the question of who a competency is for remains unresolved.

Through the literature review, we identified the necessity of taking a theoretically based research approach to answer the question of BIM jobs and their competencies. We analyzed the competencies in a more consistent and structured way by focusing on the competencies required for BIM based on the O*NET.

3. Research method

This paper analyzes BIM jobs and their competencies through the five steps illustrated in Fig. 2. This section provides only high-level descriptions of the five steps, to present a brief overview of the research method. The details for each step are provided in the next section.

- Step 1. Collect BIM-related job postings: BIM-related online job postings were searched and collected through major web search engines and job posting sites, such as 'Google.com," "CAJobdiagnosis.com," and "Totaljobs.com," for three months from May to July 2015, using "BIM," "Building Information Model," and "Building Information Modeling" as keywords. The search language was limited to English to maintain consistency during the analysis of the terms in the job postings.
- Step 2. Parse job descriptions into BIM job titles and competencies: The collected job postings were parsed into job titles and competencies.
- Step 3. Identify and group similar BIM jobs using the role and position analysis between BIM jobs: The role and position theory in SNA argues that actors with the same pattern of relationships have the same role and position in a network. These actors with the same pattern of relationships are called "structurally equivalent" in the role and position analysis [17,23]. The role and position theory was used to analyze the relations between BIM jobs to identify and group similar BIM jobs using the convergence of iterated correlations (CONCOR) method. The CONCOR method measures the structural equivalence between actors using the Pearson correlation coefficient [23]. We also validated the BIM job grouping by conducting regular equivalence with the original regular equivalence algorithm (REGE). The major difference in the structural equivalence approach

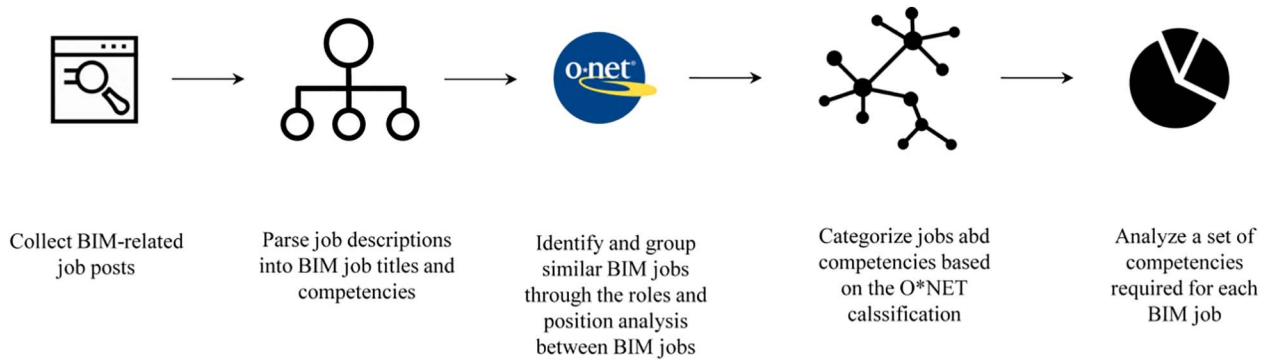


Fig. 2. Research flow.

is that the REGE focuses on the similarity of relational patterns between actors, while the CONCOR focuses on the exactness. More details on CONCOR and REGE are provided in Section 4.2, along with more particulars regarding the analysis steps and results.

- Step 4. Categorize jobs and competencies based on the O*NET classification: The parsed job descriptions and requirements were categorized using the O*NET competency classification. O*NET, as a standardized and structured format, is the most widely used job description system developed, revised, and validated by the US government [22]. Since 1995, O*NET has categorized 974 job titles of 1110 jobs using 277 competency elements in six competency domains.
- Step 5. Analyze a set of competencies required for each BIM job: Sets of competencies required for different BIM jobs were analyzed by matching the job requirements described in job postings with each BIM job. Depending on how widely each competency was required, the competencies were categorized into three groups: the essential, common, and job-specific competency groups. Details of this classification are discussed in Section 4.5.

4. BIM competency analysis

4.1. Collection of BIM-related online job postings

As described in the Research method section, online job postings were searched and collected using the keywords "BIM," "Building Information Model," and "Building Information Modeling" from major web search engines and job posting sites for three months from May to July 2015. Job postings were collected from various resources, but the three primary sources of information were "Google.com," "CAJobdiagnosis.com," and "Totaljobs.com." A total of 253 online postings for BIM-related jobs were collected from China, the US, the UK, Singapore, Canada, the United Arab Emirates (UAE), Japan, Korea, and Australia (85, 82, 75, 3, 3, 2, 1, 1, and 1, respectively). However, the number of job postings collected from the US, UK, and China (82, 75, and 85, respectively) were significant. The number of job postings collected from the other regions (i.e., UAE, Singapore, Canada, Japan, Korea, and Australia), by contrast, was small. Statistically meaningful results were obtained by excluding the job postings collected from UAE, Singapore, Canada, Japan, Korea, and Australia from the analysis. As a result, only the 242 BIM-related job postings collected from the US, UK, and China were used in the analysis.

4.2. Parsing job postings into job titles and competencies

The 242 job postings from the US, UK, and China generally comprised two sections: the job title section and the competency section. Examples of the job title section are "Architect/BIM Project Lead" and "BIM Manager." The competency section was composed of descriptions related to roles and job qualifications, such as knowledge, education, skills for specific software programs, and others.

Job requirements were described in sentences, phrases, or both. Some on-line job postings ran over two pages. The average number of sentences per job posting was 16.08 (standard deviation: 9.31) and the average number of words was 134.28 (standard deviation: 119.08). Differences existed between the lengths of job postings, but the lengths of the majority of job postings (81.40%, 197 job postings) were 10 to 200 words. The total number of words collected from the 242 job postings was 32,495. Fig. 3 below shows a histogram and the normal distribution of the number of sentences. A more detailed analysis of the job descriptions is presented in Appendix 1.

The 32,495 words collected from the 242 job postings were first parsed to derive 35 types of job titles and 5998 competency elements. The following is an example of the parsing process using this sample job description:

> "*As our BIM manager, this job requires practical knowledge of BIM modeling software and the ability to focus on the benefits BIM can add, thereby enthusing and supporting others in its adoption and use* [10]."

From this job description, the term "*BIM manager*" was used as a job title, and four competency elements were derived: "*practical knowledge of BIM modeling software*," "*ability to focus on the benefits BIM*," "*enthusing*," and "*supporting others in its adoption and use*."

Among 35 job titles, the top ten most frequently required BIM positions were BIM manager, BIM engineer, BIM coordinator, BIM technician, architect, mechanical, electrical, and plumbing (MEP) BIM

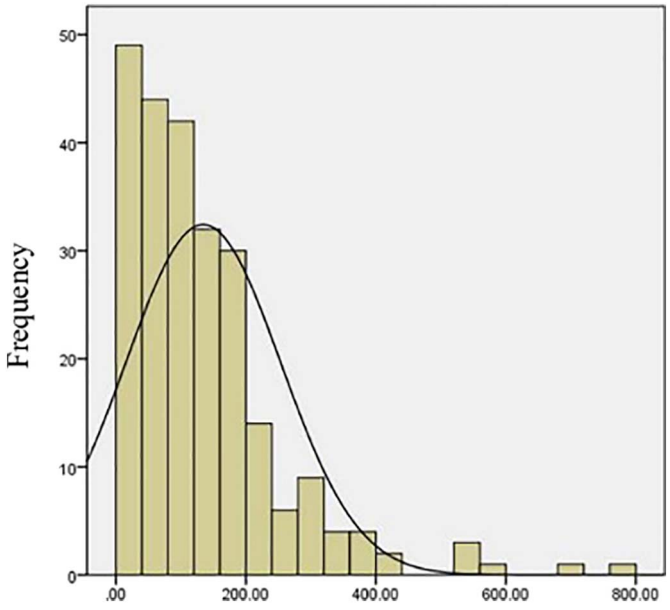


Fig. 3. A histogram of word counts in each job post with a normal distribution curve.

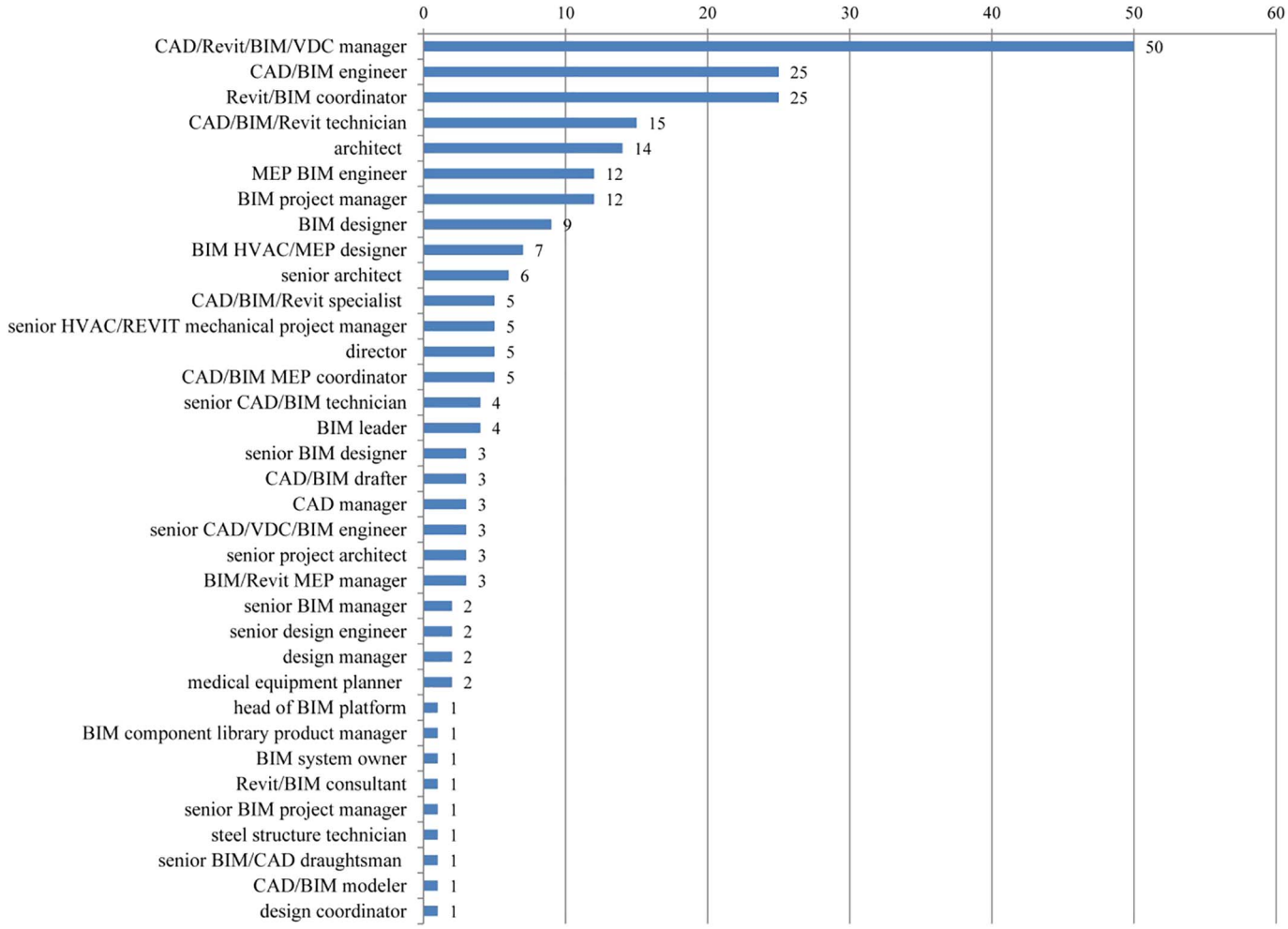


Fig. 4. Types of BIM job titles in three regions of BIM job markets.

engineer, BIM project manager, BIM designer, BIM MEP designer, and senior architect, as illustrated in Fig. 4. Among the 35 job types, BIM manager was the most frequently sought type of personnel. BIM manager was also referred to as computer aided design (CAD) manager (with BIM knowledge and skills), Revit manager, and virtual design and construction (VDC) manager, although the job descriptions were virtually identical. These titles were grouped as BIM manager. By the same token, Revit coordinator and BIM coordinator were grouped together. Although many other job types were similar, these other job types could not be objectively grouped together as one group. The next section describes the details of the identification and grouping process of similar BIM jobs, and the details of the classification of the 5998 competency elements are described in Section 4.4.

4.3. Identification and grouping of BIM jobs

The 35 BIM job types included many jobs with similar roles, such as project manager and project architect. Some job postings defined the roles of a project manager differently from those of a project architect, but many defined the roles of a project manager and a project architect similarly. This section describes how similar BIM jobs were identified and grouped.

Similar BIM jobs were identified and grouped by deploying the role and position theory as both a theoretical framework and an analysis tool. The role and position theory in SNA holds that a set of roles that shares the same pattern of relationships with other roles (i.e., is structurally equivalent [17]), can be regarded as one role group [5]. Based on the assumption of the role and position theory and the relations between BIM jobs, the on-line job descriptions were statistically analyzed using the CONCOR method. More details on the role and position analysis are provided in Section 3.

First, the 35 job titles were defined as actors in a social network and the relationships between them were defined as relations. For example, on-line BIM job descriptions contained sentences that defined the role of a BIM job as a relation between BIM jobs, such as “BIM coordinator supports BIM managers.” Therefore, BIM coordinator and BIM manager were defined as actors.

Second, the verb was defined as a relationship between the two actors. In addition to supports in the above example, other verbs such as aids, serves, provides, give, leads, receives, and is responsible for were also used. The terms supports and is supported by as an inverted relationship were used as represented terms to indicate the direction of service. These verbs had a clear direction of service and could thus be easily translated into either “supports (aids, serves, provides, gives)” or “is supported by (leads, receives, is responsible for)” according to their directionality. Any one of these terms could have been used as a representative term to indicate the direction of service.

Third, BIM jobs and their relationships were coded into an adjacency matrix and represented as a directed social network diagram (Fig. 5). The “supports” or “is supported by” relationships were expressed as inverted relationships in the network.

Fourth, a more objective and concrete result was obtained by block modeling using the convergence of iterated correlations (CONCOR) method. This method is useful for measuring the structural equivalence between actors by splitting a set into two smaller subsets. As described, CONCOR is “a commonly used block modeling method, and it utilizes

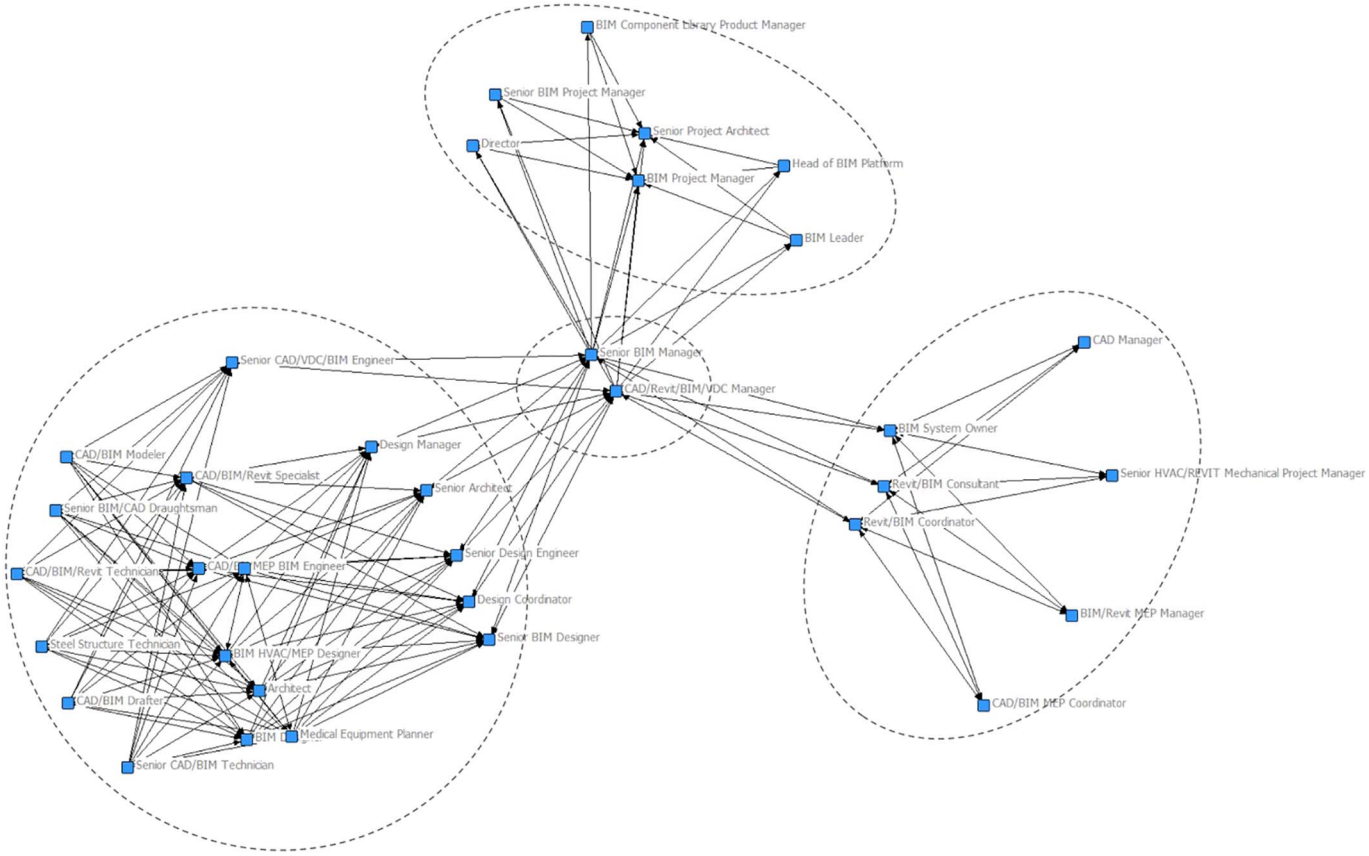


Fig. 5. Supporting relationships between BIM jobs.

the Pearson correlation coefficients as a means to measure structural equivalence between actors [23].” Structural equivalence defines two actors as equivalent if they share the same ties to the same additional actors [17]. Repeated performance of the splitting process grouped actors in a block based on the similarities between the relationship patterns of the actors. The goal of block modeling is to reduce a large network to a smaller and simpler representation for easier interpretation of the positions and roles.

Fifth, the results of the block modeling using CONCOR were used to group the 35 BIM jobs into eight blocks, as shown in Fig. 6. The matrices in Fig. 6 contain 8 × 8 blocks, with each block representing a subdivision in the network and therefore a position within the network. Each block contains the following BIM jobs:

- Block 1 (β1): BIM project manager and senior project architect
- Block 2 (β2): director, senior BIM project manager, BIM leader, head of BIM platform, and BIM component library product manager
- Block 3 (β3): Revit/BIM consultant, BIM system owner, and Revit/BIM coordinator
- Block 4 (β4): senior design engineer, senior BIM designer, design coordinator, design manager, and senior architect
- Block 5 (β5): senior BIM manager and CAD/Revit/BIM/VDC manager
- Block 6 (β6): architect, medical equipment planner, BIM designer, BIM HVAC/MEP designer, senior CAD/VDC/BIM engineer, CAD/BIM/Revit specialist, CAD/BIM engineer, and MEP BIM engineer
- Block 7 (β7): CAD manager, CAD/BIM MEP coordinator, BIM/Revit MEP manager, and senior HAVC/Revit mechanical project manager
- Block 8 (β8): CAD/BIM modeler, steel structure technician, CAD/BIM drafter, senior BIM/CAD draftsman, senior CAD/BIM technician, and CAD/BIM/Revit technician

Sixth, the blocked matrix shown in Fig. 6 also contains the density matrix. The density matrix shows the density score of each block, and the matrix displays the score in the corresponding cells. This density score, which is expressed as a number between blocks from zero (supported) to one (supporting), shows the level of the relationship between two blocks. For example, if a density score of one group is close to the number “1,” this might be the group providing support to the other group. Conversely, if one group has a density score close to the number “0,” this might be the group receiving the other group's support. In Fig. 6, the density of Block 2 is “1,” which means that Block 2 supports Block 1. The density of Block 3 against Block 5 and Block 7 is “1,” which means that Block 3 supports groups 5 and 7.

Some density scores are midway between “1” and “0.” For example, Block 6 against Block 4 is “0.875.” This value was defined as an “optional support” relation, because the blocked matrix in Fig. 6 shows that some jobs in Block 6 support jobs in Block 4, while other jobs do not support jobs in Block 4.

Seventh, based on the density matrix and R-square value, the relations among groups were represented as shown in Fig. 7.

The structural equivalence of BIM jobs was measured by block modeling using the CONCOR method. This approach for structural equivalence is effective in assigning actors to positions individually. However, validation of the relationships by comparing and arranging groups is difficult. The relationships between the eight BIM job blocks were therefore improved using the regular equivalence method, as previously suggested [23]. Prell [23] provided a clearer example, depicted in Fig. 8, which shows that the structural equivalence method assigned groups to five categories, [A], [B], [C], [D, E], and [F], and the regular equivalent method assigned groups to three categories, which are [A], [B, C], and [D, E, F].

Eighth, the eight job groups derived from block modeling using the CONCOR method were validated and improved by performing regular equivalence using the original regular equivalence algorithm (REGE). The REGE was developed for use with valued continuous data, which

Relation Sheet1
Blocked Matrix

		1 B	2 S	3 D	4 S	5 B	6 H	7 B	12 R	11 B	10 R	26 S	25 D	23 D	24 S	27 C	9 S	8 C	31 A	30 M	28 B	29 B	35 S	32 C	33 C	34 M	13 C	14 C	15 B	16 S	22 C	19 S	20 C	21 S	17 C	18 C
1	BIM Project Manager																																			
2	Senior Project Architect																																			
3	Director	1	1																																	
4	Senior BIM Project Manager	1	1																																	
5	BIM Leader	1	1																																	
6	Head of BIM Platform	1	1																																	
7	BIM Component Library Product Manager	1	1																																	
12	Revit/BIM Consultant																1	1									1	1	1	1						
11	BIM System Owner																1	1									1	1	1	1						
10	Revit/BIM Coordinator																1	1									1	1	1	1						
26	Senior Design Engineer																1	1																		
25	Senior BIM Designer																1	1																		
23	Design Coordinator																1	1																		
24	Design Manager																1	1																		
27	Senior Architect?																1	1																		
9	Senior BIM Manager	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																				
8	CAD/Revit/BIM/VDC Manager	1	1	1	1	1	1		1	1	1	1	1	1	1	1																				
31	Architect?											1	1	1	1	1																				
30	Medical Equipment Planner?											1	1	1	1	1				1		1				1										
28	BIM Designer											1	1	1	1	1																				
29	BIM HVAC/MEP Designer											1	1	1	1	1				1		1				1										
35	Senior CAD/VDC/BIM Engineer																1	1																		
32	CAD/BIM/Revit Specialist?											1	1	1	1	1																				
33	CAD/BIM Engineer											1	1	1	1	1																				
34	MEP BIM Engineer											1	1	1	1	1				1		1														
13	CAD Manager								1	1	1																									
14	CAD/BIM MEP Coordinator								1	1	1																									
15	BIM/Revit MEP Manager								1	1	1																									
16	Senior HVAC/REVIT?Mechanical Project Manager								1	1	1																									
22	CAD/BIM Modeler																		1	1	1	1	1	1	1	1					1	1	1	1	1	1
19	Steel Structure Technician																		1	1	1	1	1	1	1	1					1	1	1	1	1	1
20	CAD/BIM Drafter																		1	1	1	1	1	1	1	1					1	1	1	1	1	1
21	Senior BIM/CAD Draughtsman?																		1	1	1	1	1	1	1	1					1	1	1	1	1	1
17	Senior CAD/BIM Technician																		1	1	1	1	1	1	1	1					1	1	1	1	1	1
18	CAD/BIM/Revit Technician																		1	1	1	1	1	1	1	1					1	1	1	1	1	1

Density Matrix

	1	2	3	4	5	6	7	8
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	1.000	0.000	1.000	0.000
4	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
5	1.000	0.900	1.000	1.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.875	0.125	0.107	0.000	0.000
7	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000

R-squared = 0.915

Fig. 6. Blocked matrices of BIM job titles.

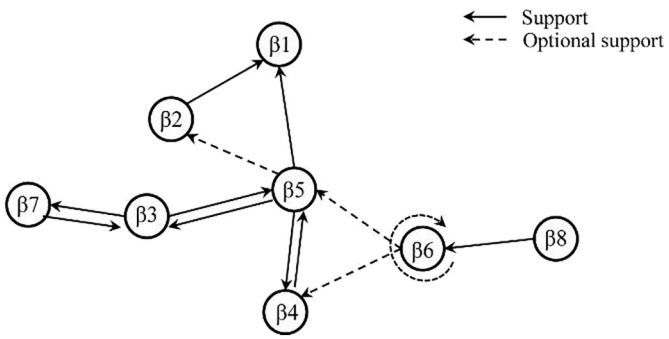


Fig. 7. Relationships between eight BIM job blocks.

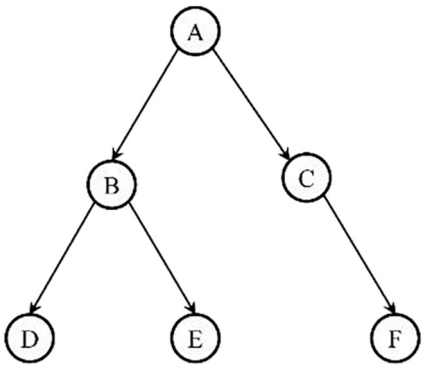


Fig. 8. An example of the difference between structural and regular equivalence by Prell [23].

measures the extent to which one BIM job's ties match another BIM job's ties [23]. According to Borgatti and Everett [6], as an iterative algorithm, the REGE algorithm begins by setting eij = 1.0 for all pairs of nodes. With each succeeding iteration, it re-computes eij for all pairs

REGE similarities (3 iterations)

		1 BIM	2 Sen	3 Dir	4 Sen	5 BIM	6 Hea	7 BIM	8 CAD	9 Sen	10 Rev	11 BIM	12 Rev	13 CAD	14 CAD	15 BIM	16 Sen	17 Sen	18 CAD	19 Ste	20 CAD	21 Sen	22 CAD	23 Des	24 Des	25 Sen	26 Sen	27 Sen	28 BIM	29 BIM	30 Med	31 Arc	32 CAD	33 CAD	34 MEP	35 Sen
1	BIM Project Manager	100	100	67	67	67	67	63	46	44	58	58	58	59	59	59	59	0	0	0	0	0	0	78	78	78	78	78	49	54	54	49	49	49	54	59
2	Senior Project Architect	100	100	67	67	67	67	63	46	44	58	58	58	59	59	59	59	0	0	0	0	0	0	78	78	78	78	78	49	54	54	49	49	49	54	59
3	Director	67	67	100	100	100	100	100	62	62	56	56	56	60	60	60	60	55	55	55	55	55	55	71	71	71	71	71	79	75	75	79	79	79	75	65
4	Senior BIM Project Manager	67	67	100	100	100	100	100	62	62	56	56	56	60	60	60	60	55	55	55	55	55	55	71	71	71	71	71	79	75	75	79	79	79	75	65
5	BIM Leader	67	67	100	100	100	100	100	62	62	56	56	56	60	60	60	60	55	55	55	55	55	55	71	71	71	71	71	79	75	75	79	79	79	75	65
6	Head of BIM Platform	67	67	100	100	100	100	100	62	62	56	56	56	60	60	60	60	55	55	55	55	55	55	71	71	71	71	71	79	75	75	79	79	79	75	65
7	BIM Component Library Product Manager	63	63	100	100	100	100	100	61	61	52	52	52	55	55	55	55	60	60	60	60	60	60	69	69	69	69	69	80	74	74	80	80	80	74	64
8	CAD/Revit/BIM/VDC Manager	46	46	62	62	62	62	61	100	100	91	91	91	89	89	89	89	61	61	61	61	61	61	90	90	90	90	90	65	88	88	65	65	65	88	57
9	Senior BIM Manager	44	44	62	62	62	62	61	100	100	90	90	90	88	88	88	88	62	62	62	62	62	62	89	89	89	89	89	65	88	88	65	65	65	88	57
10	Revit/BIM Coordinator	58	58	56	56	56	56	56	52	91	90	100	100	100	99	99	99	59	59	59	59	59	59	91	91	91	91	91	63	88	88	63	63	63	88	60
11	BIM System Owner	58	58	56	56	56	56	56	52	91	90	100	100	100	99	99	99	59	59	59	59	59	59	91	91	91	91	91	63	88	88	63	63	63	88	60
12	Revit/BIM Consultant	58	58	56	56	56	56	56	52	91	90	100	100	100	99	99	99	59	59	59	59	59	59	91	91	91	91	91	63	88	88	63	63	63	88	60
13	CAD Manager	59	59	60	60	60	60	55	89	88	99	99	99	100	100	100	100	65	65	65	65	65	65	89	89	89	89	89	69	87	87	69	69	69	87	62
14	CAD/BIM MEP Coordinator	59	59	60	60	60	60	55	89	88	99	99	99	100	100	100	100	65	65	65	65	65	65	89	89	89	89	89	69	87	87	69	69	69	87	62
15	BIM/Revit MEP Manager	59	59	60	60	60	60	55	89	88	99	99	99	100	100	100	100	65	65	65	65	65	65	89	89	89	89	89	69	87	87	69	69	69	87	62
16	Senior HVAC/REVIT?Mechanical Project Manager	59	59	60	60	60	60	55	89	88	99	99	99	100	100	100	100	65	65	65	65	65	65	89	89	89	89	89	69	87	87	69	69	69	87	62
17	Senior CAD/BIM Technician	0	0	55	55	55	55	60	61	62	59	59	59	65	65	65	65	100	100	100	100	100	100	42	42	42	42	42	58	62	62	58	58	58	62	50
18	CAD/BIM/Revit Technician	0	0	55	55	55	55	60	61	62	59	59	59	65	65	65	65	100	100	100	100	100	100	42	42	42	42	42	58	62	62	58	58	58	62	50
19	Steel Structure Technician	0	0	55	55	55	55	60	61	62	59	59	59	65	65	65	65	100	100	100	100	100	100	42	42	42	42	42	58	62	62	58	58	58	62	50
20	CAD/BIM Drafter	0	0	55	55	55	55	60	61	62	59	59	59	65	65	65	65	100	100	100	100	100	100	42	42	42	42	42	58	62	62	58	58	58	62	50
21	Senior BIM/CAD Draughtsman?	0	0	55	55	55	55	60	61	62	59	59	59	65	65	65	65	100	100	100	100	100	100	42	42	42	42	42	58	62	62	58	58	58	62	50
22	CAD/BIM Modeler	0	0	55	55	55	55	60	61	62	59	59	59	65	65	65	65	100	100	100	100	100	100	42	42	42	42	42	58	62	62	58	58	58	62	50
23	Design Coordinator	78	78	71	71	71	71	69	90	89	91	91	91	89	89	89	89	42	42	42	42	42	42	100	100	100	100	100	70	89	89	70	70	70	89	67
24	Design Manager	78	78	71	71	71	71	69	90	89	91	91	91	89	89	89	89	42	42	42	42	42	42	100	100	100	100	100	70	89	89	70	70	70	89	67
25	Senior BIM Designer	78	78	71	71	71	71	69	90	89	91	91	91	89	89	89	89	42	42	42	42	42	42	100	100	100	100	100	70	89	89	70	70	70	89	67
26	Senior Design Engineer	78	78	71	71	71	71	69	90	89	91	91	91	89	89	89	89	42	42	42	42	42	42	100	100	100	100	100	70	89	89	70	70	70	89	67
27	Senior Architect?	78	78	71	71	71	71	69	90	89	91	91	91	89	89	89	89	42	42	42	42	42	42	100	100	100	100	100	70	89	89	70	70	70	89	67
28	BIM Designer	49	49	79	79	79	79	80	65	65	63	63	63	69	69	69	69	58	58	58	58	58	58	70	70	70	70	70	100	92	92	100	100	100	92	98
29	BIM HVAC/MEP Designer	54	54	75	75	75	75	74	88	88	88	88	88	87	87	87	87	62	62	62	62	62	62	89	89	89	89	89	92	100	100	92	92	92	100	89
30	Medical Equipment Planner?	54	54	75	75	75	75	74	88	88	88	88	88	87	87	87	87	62	62	62	62	62	62	89	89	89	89	89	92	100	100	92	92	92	100	89
31	Architect?	49	49	79	79	79	79	80	65	65	63	63	63	69	69	69	69	58	58	58	58	58	58	70	70	70	70	70	100	92	92	100	100	100	92	98
32	CAD/BIM/Revit Specialist?	49	49	79	79	79	79	80	65	65	63	63	63	69	69	69	69	58	58	58	58	58	58	70	70	70	70	70	100	92	92	100	100	100	92	98
33	CAD/BIM Engineer	49	49	79	79	79	79	80	65	65	63	63	63	69	69	69	69	58	58	58	58	58	58	70	70	70	70	70	100	92	92	100	100	100	92	98
34	MEP BIM Engineer	54	54	75	75	75	75	74	88	88	88	88	88	87	87	87	87	62	62	62	62	62	62	89	89	89	89	89	92	100	100	92	92	92	100	89
35	Senior CAD/VDC/BIM Engineer	59	59	65	65	65	65	64	57	60	60	60	60	62	62	62	62	50	50	50	50	50	50	67	67	67	67	67	98	89	89	98	98	98	89	100

Fig. 9. REGE similarities of BIM job titles.

based on the degree to which i's alters correspond to j's alters. For the first iteration, eij is calculated by counting the extent to which i's ties to her alters correspond to j's ties to his alters (and vice versa) and then dividing it by the total number possible. The values of the regular equivalence in the cells represent percentages, with 0 meaning "no equivalence" and 100 meaning "perfect regular equivalence" [23]. The results of the regular equivalence analysis are shown in Fig. 9.

A clearer understanding of the results of the regular equivalence was obtained using a clustering image (Fig. 10). The clustering result in Fig. 10 was interpreted by checking and comparing the R-square values (91.5%) in Fig. 6 with the clustering diagram shown in Fig. 10. The REGE analysis result indicated the presence of eight groups, and this result was the same as the blocked matrix in Fig. 6.

Finally, after assigning the BIM jobs to eight blocks, we defined the representative BIM job titles to blocks. The representative BIM job titles are selected from the most frequent job titles by each block, based on Fig. 4. The representative BIM job titles are the titles that are most frequently used in the block.

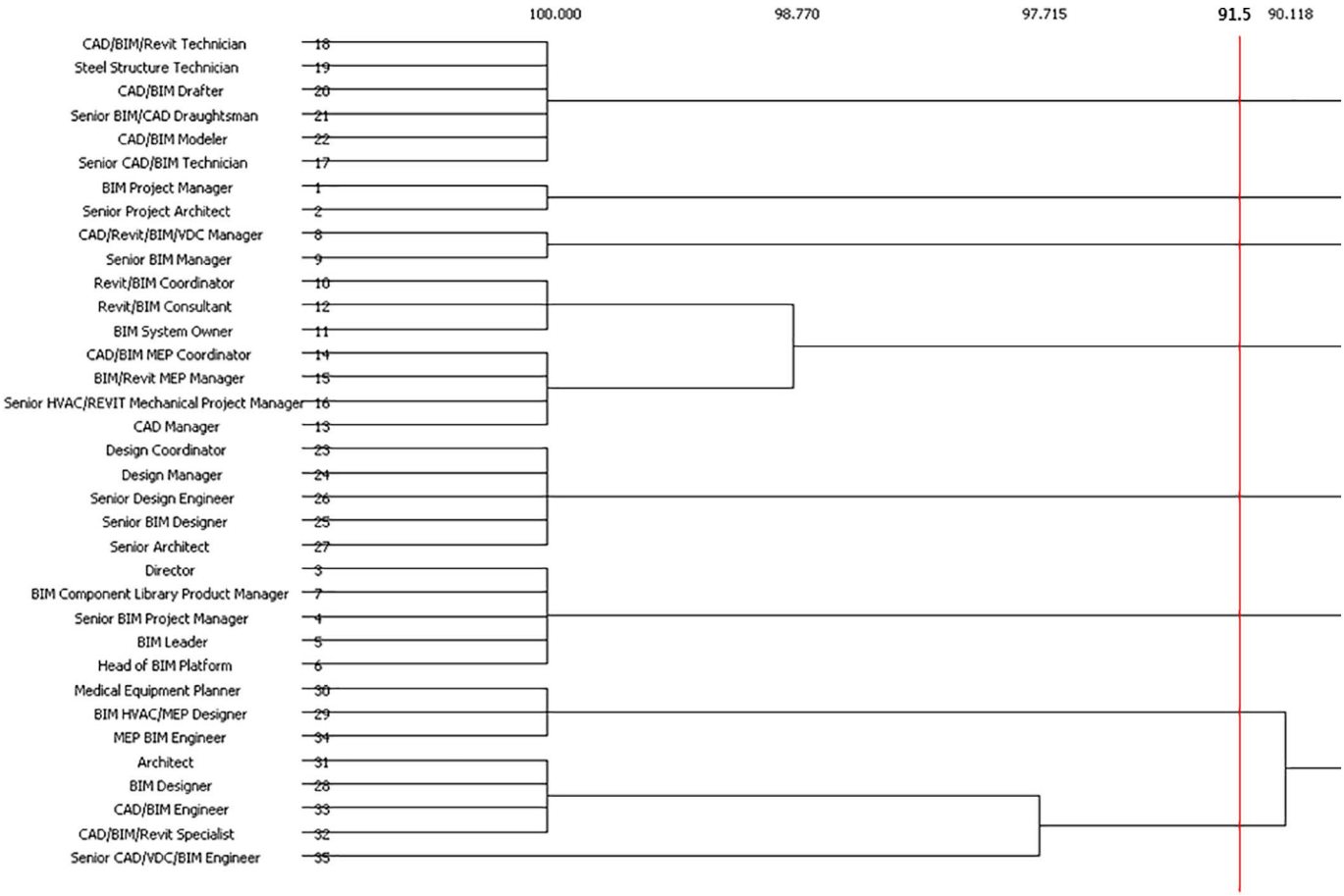


Fig. 10. Result of the REGE analysis of BIM job blocks.

Table 1
Eight BIM job groups, assigned BIM jobs, and their relations based on the block modeling and regular equivalence analysis results.

Group	Representative job title	Equivalent BIM job titles	Relations[a]
β1	BIM project manager	senior project architect	β2, β5 → β1
β2	Director	senior BIM project manager, BIM leader, head of BIM platform, and BIM component library product manager	β2 → β1 β5 ⇒ β2
β3	BIM coordinator	Revit/BIM consultant, BIM system owner, Revit/BIM coordinator	β3 ↔ β5, β7
β4	Senior architect	senior design engineer, senior BIM designer, design coordinator, design manager	β4 ↔ β5 β6 ⇒ β4
β5	BIM manager	senior BIM manager, CAD/Revit/BIM/VDC manager	β5 ↔ β1, β3, β4 β5 ⇒ β2 β6 ⇒ β5
β6	BIM designer	architect, medical equipment planner, BIM HVAC/MEP designer, senior CAD/VDC/BIM engineer, CAD/BIM/Revit specialist, CAD/BIM engineer, MEP BIM engineer	β6 ⇒ β4, β5 β8 → β6
β7	BIM MEP coordinator	CAD manager, CAD/BIM MEP coordinator, BIM/Revit MEP manager, senior HVAC/Revit mechanical project manager	β7 ↔ β3
β8	BIM technician	CAD/BIM modeler, steel structure technician, CAD/BIM drafter, senior BIM/CAD draftsman, senior CAD/BIM technician, and CAD/BIM/Revit technician	β8 → β6

[a] A supporting relation is expressed as a sign '→'or '↔,' and the optional supporting relation is expressed as a sign '⇒.'

A summary of this section is presented in Table 1, and the main results can be stated as follows. First, eight groups of BIM jobs are identified, and each group could be labeled BIM project manager, director, BIM coordinator, senior architect, BIM manager, BIM designer, BIM MEP coordinator, and BIM technician. Second, each job group includes other job titles, as shown in Table 1. Interestingly, job postings for directors and senior architects with BIM skills often omitted BIM in the job title. This may imply that knowledge of BIM is important for BIM projects, but the core value of the position is still the role of a manager. Another interesting finding is that "BIM consultant" was often used as a synonym for BIM coordinator, and "BIM specialist" was used for BIM designer and BIM engineer. BIM designer included architectural designers as well as structural designers or MEP designers (engineers). Finally, there are directions to support or to be supported in BIM jobs. Among BIM job groups, the BIM manager is at the center of the BIM job groups, which means that the BIM manager is the most linkable job to other BIM jobs.

4.4. Mapping job descriptions to O*NET job competencies

The BIM jobs and required competencies were further analyzed by first mapping the 5998 competency elements extracted from job descriptions into the 136 competency elements based on the O*NET classifications. For example, coordination-related competency terms existed in the job descriptions, such as "strong project management and task coordination skills," "confident in coordinating across multidisciplinary teams," "coordination skills," and "international coordination." These terms were grouped into one "coordination" group. After determining whether they could be one "coordination" group, the definitions of coordination elements in O*NET classifications were confirmed. In the O*NET classifications, "coordination" is defined as a skill used for "adjusting actions in relation to other's actions." A classification overlap between competency element groups was avoided by comparing the definition of "coordination element" to other similar elements, such as the "negotiation element." More detailed results of preprocessing are presented in Appendix 1. After classifying the 5998 competency elements into 136 elements groups, the frequency that a competency element was mentioned by each group was calculated. For example, 74 job postings were found for BIM designer. Among these, the negotiation skill was mentioned eight times. Therefore, the percentage of the negotiation skill as a required competency for BIM designer was 11%. The results for the required competency analysis for each BIM job group are presented in Appendix 2.

4.5. BIM job competencies analysis

As shown in Appendix 2, a total of 5998 competency terms were grouped into 136 competency elements, and the frequency analysis of competencies in each BIM job group is presented. Gaps were evident among the competency element ratios. Some elements had a considerably high ratio, while others were very low. The main competency of each BIM job group among the 136 competency elements was identified by applying the Pareto principle to the BIM job competency analysis. Known as the 80/20 rule, the Pareto principle is the simplest way to describe core competitiveness in quantitative and measurable ways [11]. The best-known example of the Pareto principle is that 20% of the work leads 80% of the work, or 20% of the workers produce 80% of the results. Use of the Pareto principle revealed that only 43 competency elements in eight competency categories were over 20% among the 136 competency elements. A total of 43 types of competency elements were over 20%, as shown in Table 2, where the gray cells indicate competency elements over 20%.

As described in the Research method section, the competencies were categorized into three types.

- A common competency: Competencies were first grouped into common (or general) and job-specific competencies. A common competency is one required by a majority of job groups (two-thirds of the job groups, more than five job groups out of eight job groups in this study). Common competencies are denoted by the symbol "●" in Table 3. Among common competencies, competencies that are required by all job groups are classified as essential competencies.
  - An essential competency: A competency that is required for all job groups. Essential competencies are denoted by the symbol "⊙" in Table 3.
- A job-specific competency: a competency that is required only by some job groups (less than two-thirds of job groups). Job-specific competencies are denoted by the symbol "▲" in Table 3. The competency elements less than two-thirds in Table 2 were contained as competency element categories, but they were limited to some BIM job groups. They were defined as job-specific competencies.

Table 3 summarizes the classification results of common, essential, and job-specific competencies. Detailed analysis results are provided in Appendix 2.

The number of common and job-specific competencies was 17 and 26, respectively. Among 17 common competencies, the number of essential competencies was 6. That is, regardless of the types of BIM jobs, all BIM jobs required "engineering and technology knowledge," "technical vocational education," "speaking skills," "work activity of interacting with computers," "work activity of establishing and maintaining interpersonal relationships," and "BIM-related work experience."

Among these competencies, BIM-related work experience differed,

Table 2
Results for BIM competency elements over 20%.

O*NET elements		BIM project manager	Director	BIM coordinator	Senior architect	BIM manager	BIM designer	BIM MEP coordinator	BIM technician
Work style	Initiative	7%	–	15%	–	12%	4%	26%	20%
	Leadership	20%	25%	4%	–	17%	9%	21%	4%
	Cooperation	13%	33%	43%	43%	38%	39%	42%	60%
Basic skills	Writing	7%	–	22%	23%	15%	12%	16%	4%
	Speaking	27%	25%	33%	21%	40%	24%	42%	32%
	Technology design	–	–	28%	7%	21%	14%	11%	8%
	Quality control analysis	7%	17%	26%		13%	–	16%	12%
	Time management	13%	17%	19%	–	15%	8%	42%	44%
	Management of personnel resources	27%	–	–	–	15%	8%	11%	–
Knowledge	Computers/electronics	7%	33%	26%	–	23%	9%	11%	–
	Engineering/technology	33%	25%	22%	21%	27%	50%	58%	44%
	Design	20%	33%	33%	57%	33%	24%	42%	32%
	Building/construction	7%	8%	11%	7%	13%	30%	53%	8%
	Mechanical	–	–	15%	–	8%	4%	21%	16%
	English language	33%	–	7%	50%	6%	20%	–	8%
	Foreign language	27%	25%	7%	–	2%	18%	5%	–
	Law/government	33%	8%	33%	–	21%	19%	21%	16%
Education	Technical vocational	60%	42%	30%	21%	25%	39%	37%	44%
Experience	Related work experience	73%	83%	52%	57%	52%	72%	47%	40%
Licensing	License or registration required	33%	33%	4%	7%	6%	14%	26%	4%
	Post–secondary degree	47%	67%	37%	–	33%	64%	42%	48%
	Graduate degree	33%	–	4%	–	6%	5%	–	4%
Generalized work activities	Evaluating information to determine compliance with standards	20%	33%	37%	36%	29%	11%	37%	44%
	Making solving problems	13%	–	7%	29%	15%	8%	5%	16%
	Thinking creatively	20%	33%	22%	29%	21%	29%	21%	52%
	Scheduling work and activities	13%	25%	19%	14%	19%	8%	21%	8%
	Organizing, planning, and prioritizing work	20%	8%	26%	7%	17%	5%	16%	12%
	Interacting with computers	67%	83%	81%	64%	77%	72%	84%	84%
	Drafting, laying out, specifying technical device, equipment	20%	42%	63%	43%	48%	59%	47%	76%
	Documenting/recording	13%	17%	44%	21%	40%	7%	26%	40%
	Communicating with supervisors, peers	13%	25%	26%	–	31%	15%	26%	32%
	Establishing, maintaining interpersonal relationships	47%	42%	44%	50%	48%	30%	53%	48%
	Coordinating the work and activities of others	33%	–	15%	7%	13%	23%	16%	24%
	Training and teaching others	13%	–	26%	–	42%	9%	21%	20%
	Guiding, directing, and motivating subordinates	27%	25%	48%	–	44%	5%	21%	16%
	Provide consultation and advice	20%	33%	26%	29%	25%	–	32%	16%
	Performing administrative activities	20%	8%	22%	–	13%	23%	21%	8%
Organizational context	Have control over unit or department	20%	25%	4%	–	17%	4%	16%	–
	Monitor data on quality/costs/waste/etc.	13%	25%	41%	21%	42%	5%	42%	28%
	Determine workflow or order of tasks	7%	25%	15%	–	25%	4%	11%	4%
	Develop new products, services, and procedures	–	25%	11%	–	17%	1%	5%	4%
	Opportunity for independence freedom	7%	25%	15%	–	10%	9%	–	4%
	Providing high quality products	7%	–	19%	14%	10%	11%	21%	20%

* Numbers in gray cells indicate over 20% of the each BIM jobs′ main competencies.

depending on the BIM job. As illustrated in Fig. 11, a BIM project manager required an average of 7.3 years of BIM-related work experience. A director was required to have an average of 8.1 years. A BIM coordinator was required to have an average of 4.5 years, and a senior architect was required to have an average of 8 years. BIM manager, BIM designer, BIM MEP coordinator, and BIM technician were required to have 5.8 years, 3.6 years, 9.2 years, and 2.4 years, respectively. BIM MEP coordinators required the most work experience, while BIM technicians required work experience from eight groups. A four-fold difference existed between a BIM MEP coordinator and a BIM technician. The BIM manager also required much more work experience than did a BIM coordinator.

The remaining 11 common competencies required by 5 to 7 job groups were “cooperative” work style, general work activities of

Table 3
Illustration of common, essential, and job-specific competencies with signs*.

O*NET elements		BIM project manager	Director	BIM coordinator	Senior architect	BIM manager	BIM designer	BIM MEP coordinator	BIM technician
Work style	Initiative							▲	
	Leadership		▲					▲	
	Cooperation		●	●	●	●	●	●	●
Basic skills	Writing			▲	▲				
	Speaking	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
	Technology design			▲		▲			
	Quality control analysis			▲					
	Time management							▲	▲
	Management of personnel resources	▲							
Knowledge	Computers/electronics		▲	▲					
	Engineering/technology	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
	Design		●	●	●	●	●	●	●
	Building/construction						▲	▲	
	Mechanical							▲	
	English language	▲			▲				
	Foreign language	▲	▲						
	Law/government	▲				▲		▲	
Education	Technical vocational	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
Experience	BIM–related work experience	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
Licensing	License or registration required	▲	▲					▲	
	Post–secondary degree	●	●	●		●	●	●	●
	Graduate degree	▲							
Generalized work activities	Evaluating information to determine compliance with standards		●	●	●	●		●	●
	Making solving problems				▲				
	Thinking creatively		●	●	●	●	●	●	●
	Scheduling work and activities		▲					▲	
	Organizing, planning, and prioritizing work			▲					
	Interacting with computers	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
	Drafting, laying out, specifying technical device, equipment		●	●	●	●	●	●	●
	Documenting/recording			●	●	●		●	●
	Communicating with supervisors, peers		●	●		●		●	●
	Establishing, maintaining interpersonal relationships	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
	Coordinating the work and activities of others	▲					▲		▲
	Training and teaching others			▲		▲		▲	
	Guiding, directing, and motivating subordinates	●	●	●		●		●	
	Provide consultation and advice		●	●	●	●	●	●	
	Performing administrative activities			▲			▲	▲	
Organizational context	Have control over unit or department		▲						
	Monitor data on quality/costs/waste/etc.		●	●	●	●	●	●	●
	Determine workflow or order of tasks		▲			▲			
	Develop new products, services, and procedures		▲						
	Opportunity for independence and freedom		▲						
	Providing high–quality products							▲	

* Sign "⊙" indicates essential competency, "●" common competency, and "▲" job–specific competency.

"evaluating information to determine compliance with standards," "drafting, laying out, and specifying technical device, parts, and equipment," "thinking creatively," "communicating with supervisor and peers," "providing consultation and advice," "documenting and recording," "guiding, directing, and motivating subordinates," and an organizational context to "monitor data on quality, cost, waste, etc.," "design knowledge," and "post-secondary degree."

The 26 types of job-specific competency elements were analyzed based on the O*NET's six competency categories: skill, knowledge, licensing, generalized work activity, organizational context, and work style.

First, the skill category included five job-specific competencies related to BIM jobs: writing skills (S1), technology design skills (S2), quality control analysis skills (S3), time-management skills (S4), and personnel resources management skills (S5). Fig. 12 shows the analysis results indicating the degree to which each skill is required for each job group. Writing skills (S1) were required more often for the senior architect group and the BIM coordinator group than for the other job groups. Technology design skills (S2) were required most often for the BIM coordinator group and the BIM manager group. Quality control

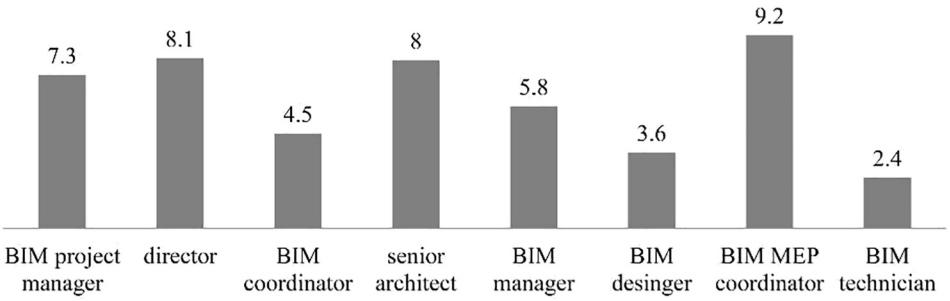
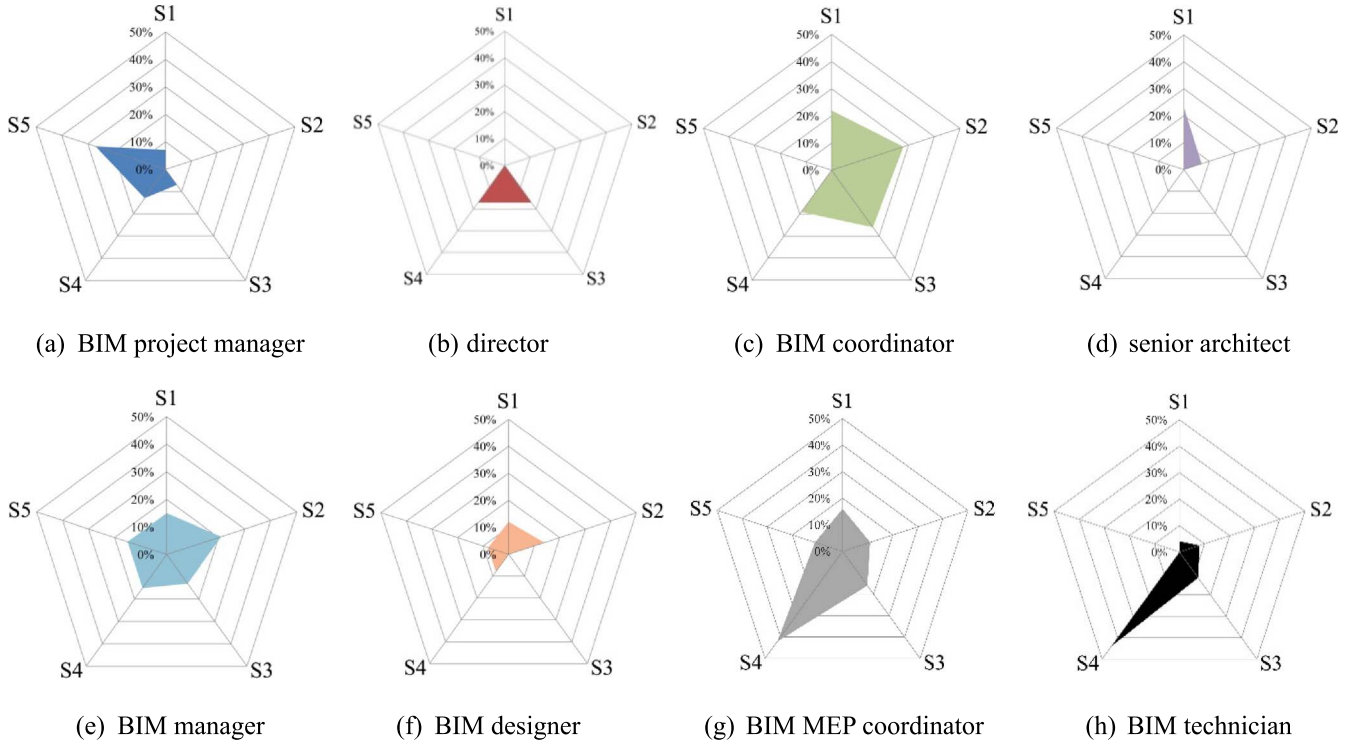


Fig. 11. Average years of required BIM-related work experience by the BIM job.



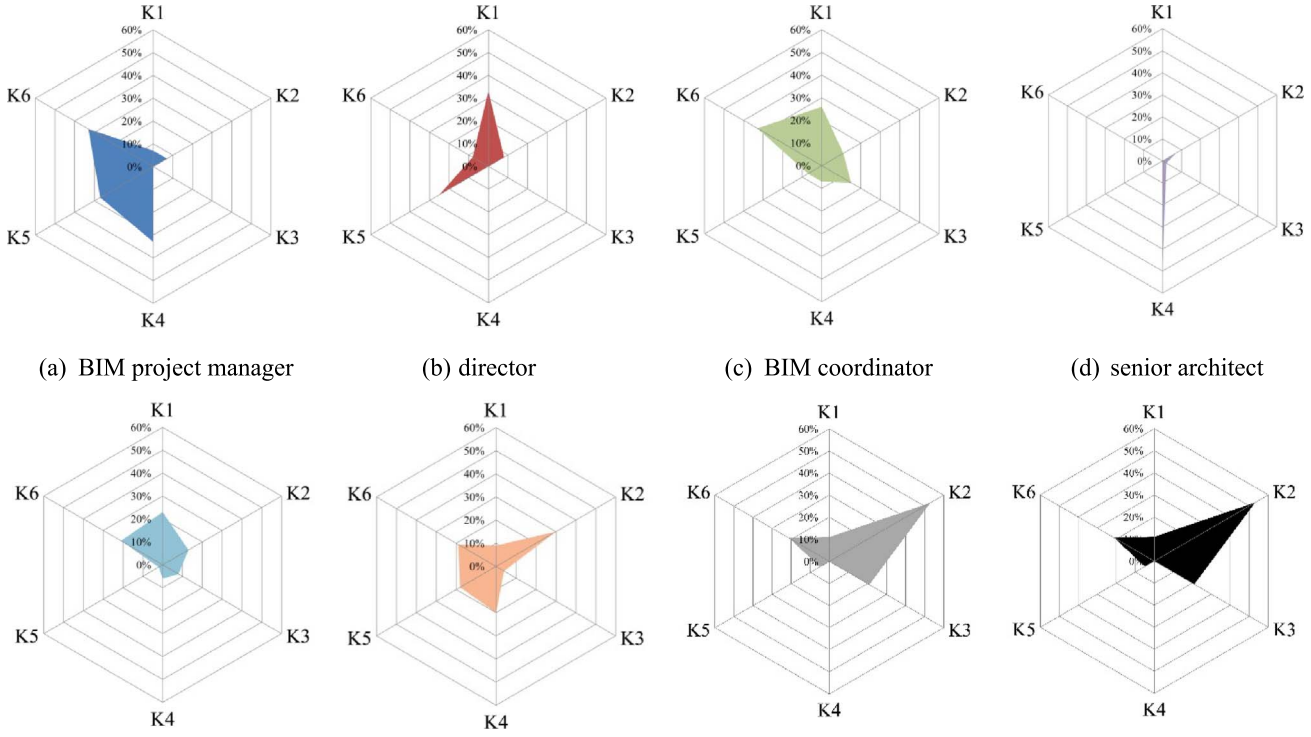
S1: writing skill; S2: technology design skill; S3: quality control analysis skill; S4: time-management skill; S5: personnel resources management skill

Fig. 12. Comparison of skills required by eight BIM job groups.

analysis skills of conducting tests and inspections of products, services, or processes to evaluate quality or performance (S3) were required most often for the BIM coordinator group. Time-management skills for themselves and others (S4) were required for the BIM MEP coordinator group and the BIM technician group. Personnel resources management skills to motivate, develop, and direct people (S5) were required most often for the BIM project manager, while the other groups placed little emphasis on personnel resource management skills. In particular, the BIM manager and BIM coordinator, which are both BIM job types that are often at the center of discussion regarding the classification of BIM jobs, showed a major difference in personnel resource management skills (S5): the BIM manager required personnel resource management skills (S5), whereas the BIM coordinator did not. Likewise, the BIM MEP coordinator and the BIM technician had similar patterns, but the BIM MEP coordinator required personnel resource management skills (S5) more often.

Second, the knowledge category includes six competencies related to BIM jobs: computer/electronics knowledge (K1), building/construction knowledge (K2), mechanical knowledge (K3), English knowledge (K4), foreign language knowledge (K5), and law/government knowledge (K6). Fig. 13 illustrates the analysis results for the degree to which each knowledge type is required by each job group. Computer and electronics related knowledge (K1) was required most often for the BIM director, followed by the BIM coordinator, BIM manager, BIM MEP coordinator, BIM technician, BIM designer, and BIM project manager. Building and construction knowledge (K2) was required for the BIM technician, BIM MEP coordinator, and BIM designer. Mechanical knowledge (K3) was required for the MEP BIM coordinator and BIM technician. English knowledge (K4) refers to knowledge of the English language, including the meaning and spelling of words, rules of composition, and grammar. Foreign language knowledge (K5) refers to languages other than English. In the collected job postings, the most commonly required foreign languages were Chinese, German (rarely), and Japanese. Law or government related knowledge (K6) included the knowledge of laws, legal codes, court procedures, precedents, government regulations, executive orders, agency rules, and the democratic political process. In addition, this was expressed in BIM job postings as knowledge of the National Electric Code (NEC), the BIM standard of BIM level 2 and a Public Available Specification (PAS) 1192-2:2007, American Institute of Architect (AIA) standards, or the Office of Statewide Health Planning and Development (OSHPD).

As in the skill category, the BIM coordinator and BIM manager, as



(a) BIM project manager (b) director (c) BIM coordinator (d) senior architect

(e) BIM manager (f) BIM designer (g) BIM MEP coordinator (h) BIM technician

K1: computer/electronics knowledge; K2: building/construction knowledge; K3: mechanical knowledge; K4: English; K5: foreign language; K6: law/government knowledge

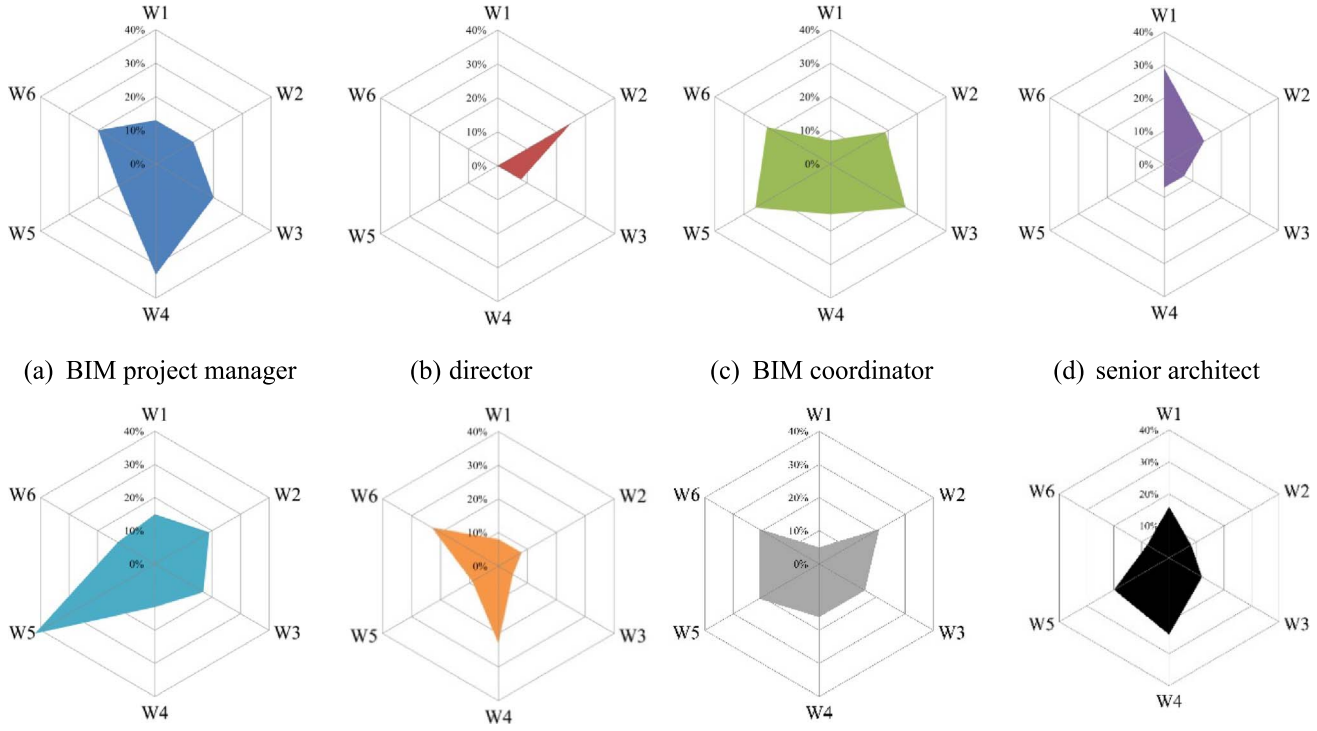
Fig. 13. Comparison of knowledge required by eight BIM job groups.

well as the BIM MEP coordinator and BIM technician, showed similar patterns in the knowledge category. In terms of knowledge, these two pairs of BIM job groups were too similar to determine a difference. However, a gap was noted among BIM job groups. A senior architect differed from other BIM jobs that required only English knowledge (K4). The BIM project manager also differed from a director. The BIM project manager required English knowledge (K4), foreign language knowledge (K5), and law or government knowledge (K6), while the director required computer and electronics knowledge (K1) and foreign language knowledge (K5). In addition, the required competencies for the BIM project manager differed from those of the BIM manager. The BIM project manager required English knowledge (K4), foreign language knowledge (K5), and law or government knowledge (K6), while the BIM manager required computer and electronics knowledge (K1).

Third, the generated work activity category included six job-specific competencies related to BIM jobs: making decisions/solving problems (W1); scheduling work and activities (W2); organizing, planning, and prioritizing work (W3); coordinating the work and activities of others (W4); training and teaching others (W5); and performing administrative activities (W6). Fig. 14 shows the analysis results for the degree to which work activities are required for each job group. Making decisions or solving problems (W1) was required for a senior architect. Scheduling work and activities for others (W2) was required for a director, BIM coordinator, and BIM MEP coordinator. Organizing, planning, and prioritizing work for oneself (W3) was required for the BIM project manager and BIM coordinator. Coordinating work and activities for others (W4) was required for the BIM project manager, BIM designer, and BIM technician. Training and teaching others (W5) was required for the BIM manager and BIM coordinator. However, this work activity was a high possibility for a BIM manager because it was often a requirement for the BIM manager as well. Performing administrative work activity (W6) was required for the BIM project manager, BIM coordinator, BIM designer, and BIM MEP coordinator.

The work activity category differed depending on the BIM job. Organizing, planning, and prioritizing work for oneself (W3), coordinating work and activities for others (W4), and performing administrative work (W6) were required for the BIM project manager, while a director was required to perform the work of scheduling other's work and activities (W2). This difference between a BIM project manager and a director indicates that the BIM project manager is responsible for coordinating all participant groups in a much broader context when compared to a director. The BIM manager and BIM coordinator also differed, as the primary responsibility for a BIM manager was training and teaching others (W5), while the primary responsibility of a BIM coordinator was prioritizing work for oneself (W3), training and teaching others (W5), and performing administrative work (W6).

Fourth, the organizational context category included five job-specific competencies related to BIM jobs. In the organizational context category, BIM jobholders could expect to have control over units or departments (O1); to determine the workflow or order of tasks (O2); to develop new products, services, and procedures (O3); to have an opportunity for independence and freedom in completing the job (O4); and to provide high-quality products or services (O5). Fig. 15 shows the analysis results for the degree to which each organizational context is required for each job group. The responsibility of control over units or departments (O1) was required for the BIM project manager and director. An organizational context of determining workflow or the order in which tasks were performed (O2) was required for a director and the BIM manager. An organizational context of developing new products, services, and procedures (O3) was required for a director. An organizational context of opportunity for independence and freedom during work (O4) was required for a director. An organizational context of providing high-quality products or services (O5) for meeting high standards was required for the BIM MEP coordinator and BIM

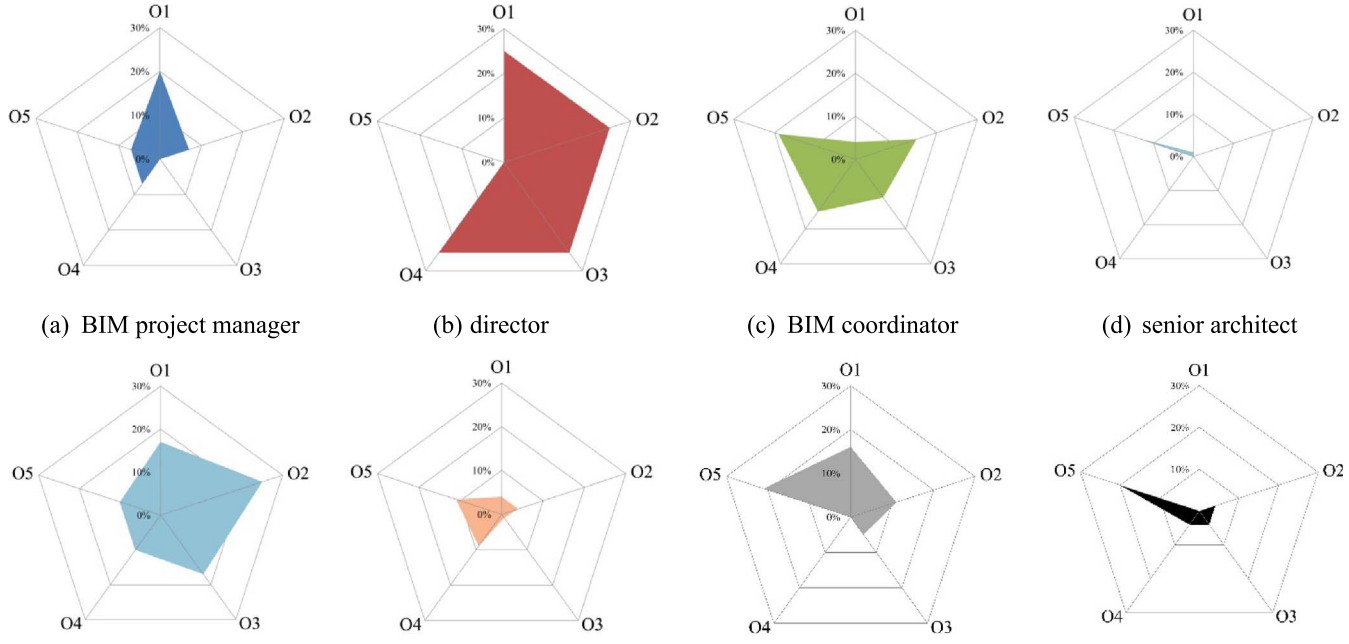


(a) BIM project manager (b) director (c) BIM coordinator (d) senior architect

(e) BIM manager (f) BIM designer (g) BIM MEP coordinator (h) BIM technician

W1: work activity of making decisions/solving problems; W2: scheduling works and activities for others; W3: work activity of organizing, planning, and prioritizing for oneself; W4: work activity of coordinating works and activities of others; W5: work activity of training and teaching others; W6: performing administrative activities

Fig. 14. Comparison of the competency category of generated work activity by job group.



(a) BIM project manager (b) director (c) BIM coordinator (d) senior architect

(e) BIM manager (f) BIM designer (g) BIM MEP coordinator (h) BIM technician

O1: organizational context to have control over unit or department; O2: organizational context to determine the workflow or the order of tasks; O3: organizational context to develop new products, services, and procedures; O4: organizational context to have an opportunity for independence and freedom; O5: organizational context to provide high-quality products or services

Fig. 15. Comparison of the competency category of an organizational context by job group.

Table 4
Comparison of groups in the work style category.

	BIM project manager	Director	BIM coordinator	Senior architect	BIM manager	BIM designer	BIM MEP coordinator	BIM technician
Initiative	7%	–	15%	–	12%	4%	26%	20%
Leadership	20%	25%	4%	–	17%	9%	21%	4%

Table 5
Required license competencies for BIM jobs.

	BIM project manager	Director	BIM coordinator	Senior architect	BIM manager	BIM designer	BIM MEP coordinator	BIM technician
License	33%	33%	4%	7%	6%	14%	26%	4%
Graduate degree	33%	–	4%	–	6%	5%	–	4%

technician.

Interestingly, an organizational context of determining workflow or the order in which tasks were performed (O2) was required for the BIM manager, but nothing in the organizational competency category was required for the BIM coordinator. Both the BIM MEP coordinator and the BIM technician were required to provide high-quality products or services (O5) for meeting high standards. In this competency category, a director was required to have more competencies when compared to the other jobs. A director was required to have control over units or departments (O1); to determine workflow or order of tasks (O2); to develop new products, services, and procedures (O3); and to have the opportunity for independence and freedom in completing the work (O4).

Fifth, the work activity category included two job-specific competencies related to BIM jobs: initiative and leadership work styles. An initiative work style was defined as a willingness to accept responsibilities and challenges. The term “initiative” was described in the job posting as a “self-motivated work ethic, with the ability to be effective and timely while providing consistent follow-up.” A leadership work style was defined as the willingness to lead, take charge, and offer opinions and direction. This category did not produce an analyzed result of job-specific competencies as a spider chart figure because this category was composed of two competency elements, and the use of a spider map is unnecessary when comparing two elements. Neither the BIM manager nor the BIM coordinator were required to have an initiative or leadership work style. Rather, an initiative work style was required for the BIM MEP coordinator, and a leadership work style was required for the BIM MEP coordinator and director (Table 4).

Sixth, the license category included two job-specific competencies related to BIM jobs: a license and a graduate degree. Similar to the work style competency category, this category only included two competency elements, which are shown in Table 5.

A license was required for the BIM project manager, director, and BIM MEP coordinator. A graduate degree was required for the BIM project manager. The licenses required were the architecture license, leadership in energy and environmental design (LEED), computer-aided design and drafting (CADD), driver's license, and professional engineer (PE). Additional details are provided in Appendix 1.

5. Implications for BIM education, training, and employment

As Wu and Issa [32] noted, due to the cyclic relation between the BIM job market and BIM education, the research findings of this study from the online job posting analysis of the BIM market have significant implications for BIM education, training, and employment.

Several academic programs are struggling to meet industrial expectations [12]. However, an erroneous assumption is still made that BIM education should only improve the BIM software application skills for students and employees [32]. In contrast to this limited view, this study has shown that competencies for BIM jobs require BIM skills as well as various types of skills, knowledge, work styles, and work activities. For example, the buildingSMART Korea [7] has offered an education program for BIM coordinators and BIM technicians since 2013. However, the program only focuses on skill development in areas such as BIM modeling, technical analyses with computers, and drawing and documenting skills. Similarly, the BIM education program offered by the Associated General Contractors of America (AGC) in the US for construction professionals [2] suffers from the same problem. The AGC BIM education program offers education on required BIM-related knowledge and operation skills but lacks education programs for many other competency criteria.

Second, the need for a certified BIM education program has been raised by several BIM experts [28]. The findings of this study can be used as a basis for developing these certified BIM education programs. Fig. 16 presents an example that illustrates the three-level education requirements for eight BIM roles. Fig. 16 provides a roadmap for becoming an expert in each role. Required competencies are categorized into essential, common, and job-specific competencies. The essential competencies can be considered as basic-level core courses, but the essentiality does not necessarily indicate the level of difficulty. Thus, the roadmap can be regrouped to form a logical sequence of education based on the level of difficulty or the level of knowledge required. In addition, the analyzed classification for BIM jobs and competencies can be used as a guide to employ or assess BIM personnel.

6. Conclusions and discussion

Although the “BIM” prefix in job advertisements has been popular in the AEC industry, its use is still debatable due to the ambiguous terms used for BIM jobs. To resolve the continuous debate regarding the job titles and duties of BIM jobs, several researchers have suggested ways to describe BIM jobs based on research results; however, the debate continues. The aim of this study was to provide industry-oriented answers to these questions. The utilization of the SNA to identify BIM jobs and their relationships, the BIM job requirement competency analysis based on the O*NET content model, and the Pareto principle allowed derivation of the following conclusions.

First, eight types of BIM jobs were identified in this study through a role and position analysis of 35 different job titles collected from 242 BIM-related job postings from the UK, US, and China. The eight BIM job types included BIM project manager, director, BIM manager, BIM coordinator, BIM designer, senior architect, BIM MEP coordinator, and BIM technician. The results of the BIM job classification produced three interesting findings. One, the term “BIM” was not used for a director or

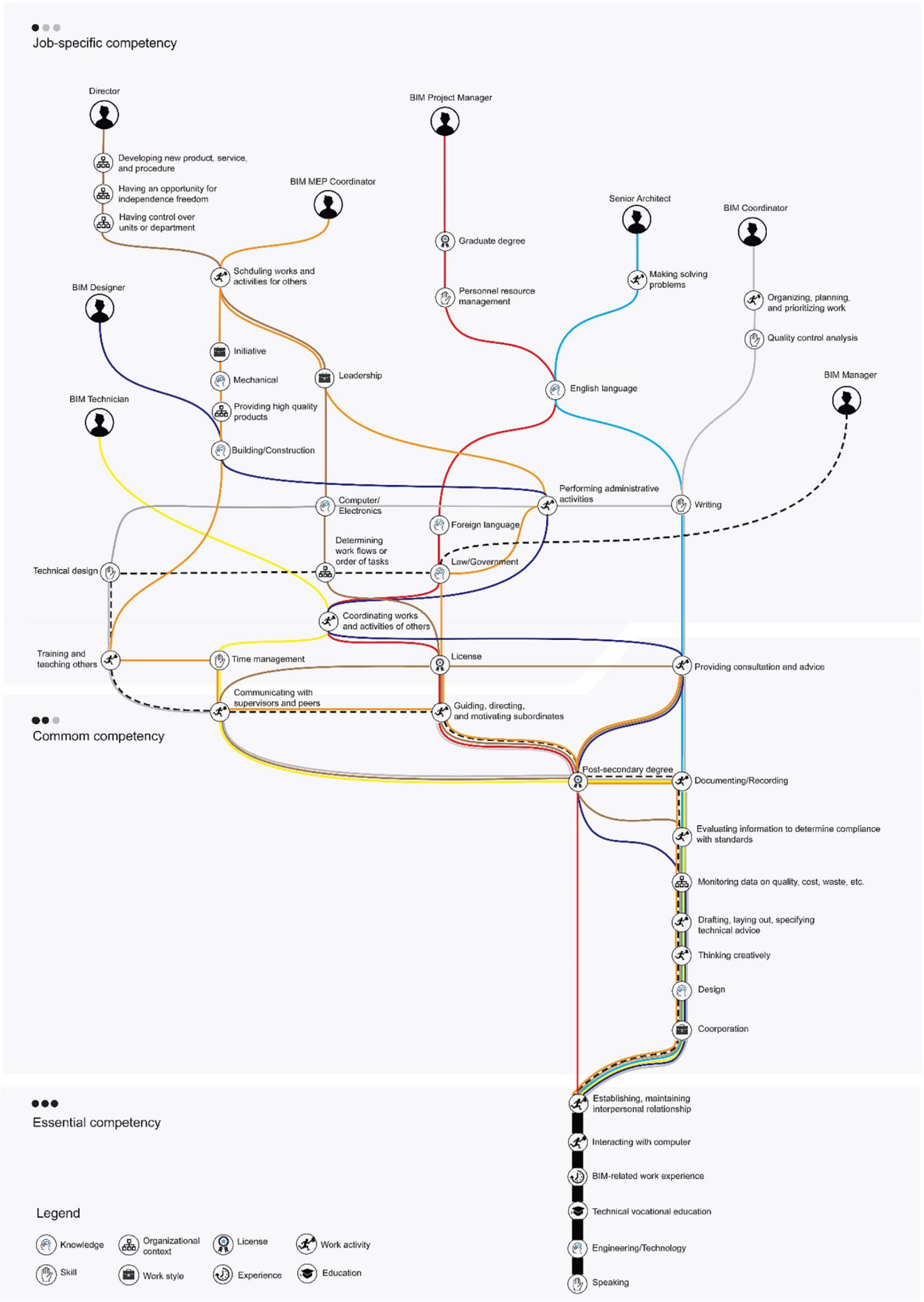


Fig. 16. A three-level education roadmap for eight BIM roles.

senior architect. This might indicate that these jobs play important roles in BIM projects, but the core role of the positions is still the role of manager. Two, the BIM coordinator was included in the group of BIM consultants. Finally, the BIM designer included architectural designers, structural designers, and MEP designers (engineers).

Second, 43 types of competencies were derived from the job descriptions and were classified into three categories (i.e., essential, common, and job-specific competencies) based on the O*NET content model and the Pareto principle. The three competency categories revealed differences among BIM jobs. The "essential" category included competencies that were required for all BIM job groups regardless of BIM job type: "speaking skill," "engineering and technology related knowledge," "technical vocational education," "BIM-related work experience," "work activity of interacting with computers," and "work activity for establishing and maintaining interpersonal relationships." In addition to the "essential" competency category, "common" competencies were required by a majority of job groups (more than five job groups out of eight job groups). Common competencies were "work style of cooperation," "design knowledge," "post-secondary degree," "work activity of evaluating information to determine compliance with standards," "work activity of thinking creatively," "work activity of documenting or recording," "work activity of communicating with supervisors and peers," "work activity of guiding, directing, and motivating subordinates," "work activity of providing consultation and advice," and "organizational context to monitor data on quality/costs/waste/etc." Interestingly, BIM project manager did not require the common competencies of "work style of cooperation," "design knowledge," "work activity of evaluating information to determine compliance with standards," "work activity of thinking creatively," "work activity of documenting or recording," "work activity of communicating with supervisors and peers," "work activity of providing consultation and advice," or "organizational context to monitor data on quality/costs/waste/etc." BIM designer did not require "work activity of evaluating information to determine compliance with standards," "work activity of documenting or recording," "work activity of communicating with supervisors and peers," or "work activity of providing consultation and advice."

The job-specific competency category was only required by some job groups (less than two-thirds of job groups). Job-specific competencies showed unique competencies between two ambiguous BIM jobs, such as the BIM manager and BIM coordinator. Both required the same common competencies; however, the BIM coordinator required "writing skills," "quality control analysis skills," "computer and electronics knowledge," "work activity of organizing, planning, and prioritizing work for oneself," "work activity of performing administrative activity," which were not required for a BIM manager. On the other hand, a specific competency for the BIM manager was "work activity of training and teaching others." In addition to this competency, "law and government related knowledge" and "organizational context to determine work flow or order of tasks for others" were required for the BIM manager but not for the BIM coordinator. Another example is that both the BIM MEP coordinator and the BIM technician required "building and construction knowledge" and "mechanical knowledge"; however, required work activities for the BIM MEP coordinator differed from those for the BIM technician. The BIM MEP coordinator required the work activities "scheduling works and activities," "performing administrative activities," and "training and teaching others," while the BIM technician required the work activity "coordinating works and activities of others."

This study may contribute to the research, industry, education as follows:

- From a research point of view, the first step of building a body of scientific knowledge is to develop definitions and classifications of concepts. BIM roles and competencies are a relatively new field of study. This study derives a classification of BIM jobs and their competencies based on how we use them today by analyzing a statistically significant amount of terms (approximately 6000 terms) related to BIM jobs and competencies in 242 job postings from three different regions rather than by relying on experts' views.
- From an industry point of view, the results of this study can be used as a guide to developing a training program by BIM job or establishing criteria for hiring BIM personnel. The results of the CONCOR analysis used in this study showed that the roles and competencies required for each job differed within the project, even if the jobs were perceived to be similar. This can also be used a foundation for developing certificate programs for BIM jobs.
- From a pedagogical point of view, the analysis results can be used as a foundation for setting up a national competence standard for BIM jobs. Based on the national competence standard, universities can develop structured BIM education programs tailored for different education goals.

Nevertheless, realization of these contributions still faces many hurdles. Although this study was conducted based on the descriptions of BIM-related job types and job requirements developed over the past 15 years in the industry, the AEC and BIM industries are continuously evolving, and the roles and competencies for BIM jobs may vary in the future. Thus, these tentative conclusions regarding BIM jobs and their competencies require further refinement and corrections based on further research.

Acknowledgements

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Appendix A. Appendix

Appendix 1
Matching O*NET Competency elements [31] with BIM job descriptive terms.

O*NET elements					BIM job descriptive terms
Level 1	Level 2	Level 3	Level 4	Level 5	
Work characteristics	Abilities	Physical abilities			Healthy, good health, lift and/or move up to 75 lb.
		Sensory abilities	Visual abilities	Visual color discrimination	Visual acuity in near, mid and far range color vision, peripheral vision, depth perception, hand/eye coordination.
	Interests	Occupational interests	Investigative		Research in the field of BIM, carry out the research, continuous research and

				development breakthroughs, ability to think strategically and research, passionate about BIM and driving the process forward.
	Work value	Recognition	Advancement	Visionary, interest in new technology and innovative solutions.
			Recognition	Clear vision of their chosen career.
			Authority	Influence and drive, enjoys training others.
		Independence	Creativity	Creative and execution.
			Responsibility	Responsibilities, self-motivated, be confident in own ability, willingness to take on additional responsibilities and manage priorities.
Work styles	Achievement orientation	Achievement/effort		Meet established goals, professionalism, drive, the ability to work in a fast-paced, challenging environment, results-oriented, professional conduct and high respect for confidentiality, highly motivated, proactive and willing to take on new challenges, meet utilization goals, establishing focus, ambitious and driven, continuously challenges what he/she does and why, desire to challenge, drive for results.
		Persistence		Perseverance, persistent nature and integrity for maintaining comprehensive and accurate data, patient, steadfast, steady.
		Initiative		Initiative, strong, self-motivated work ethic with ability to be effective and timely while providing consistent follow-up, self-starter, strong initiative, able to work on your own initiative, able to demonstrate initiative.
	Social influence	Leadership		Leadership, ability to influence people at all levels across the organization, ability to lead and develop others.
	Interpersonal orientation	Cooperation		Collaborate and coordinate with design, construction management and other, collaborates with other lead professionals, teamwork, team spirit and communication, energetic collaborative and team player, comfortable in team environment, collaborative nature, ability to interface with all levels of personnel.
		Concern for others		Strong sense of service, careful and meticulous, considered and understood, eager to support staff with positive attitude, understands the importance of positively managing one's own and others emotions.
	Adjustment	Stress tolerance		Ability to work under pressure, able to prioritize duties and work effectively under pressure, resilient in the face of setback and pressure, responsibilities in high-stress situations.
		Adaptability/ flexibility		Adaptability, comfortable balancing multiple roles, change agent responsible for change management, ability to adapt to frequent change, flexible attitude, enthusiastic and flexible approach to work.
	Conscientiousness	Attention to detail		Meticulous, strong detailing skills, attention to detail, an eye for detail,

				careful and precise.
			Integrity	Earnest, integrity, demonstrates a strong work ethic.
		Independence		Work independently, individual decisions, own initiative and work without excessive supervision.
		Practical intelligence	Innovation	Develops innovative solutions, innovation ability, innovative spirit, passionate about delivering creative, innovative approaches, creativity.
			Analytical thinking	Methodical and analytical approach to work, strong analytical skills.
Worker requirements	Basic skills	Content	Active listening	Verbal communication skills including listening and questioning.
			Writing	Fluent written English, excellent communications skills both written and verbal, excellent report writing, ability to communicate effectively in presentations and in writing.
			Speaking	Communication skills, oral and written communication skills, speeches, strong verbal communication skills, strong presentation skills and confidence to evangelize. Speak in small or large groups, precise communicator.
			Mathematics	Numerate, good math skills, strong mathematical skills, calculations.
		Process	Critical thinking	Strong analytical skills.
			Active learning	You should be able to show a willingness to learn, proactive approach to new skills and learning, a quick learner, ability to quickly learn new software tools and then teach others, self-learning ability, love and self-learning ability.
			Learning strategies	Increase knowledge and exhibit ability to learn and apply new skills, personal self-development, sharing of skills and appropriate use of individual specialist.
			Monitoring	Establish trade package design deliverables and monitor, ability to setup and run clash detection, defining tolerances and checking results, monitoring the production & functionality, capable of reviewing deliverable work of others, ensure that all work carried out is in compliance with company standards, understand and work to space management principles quality analysis (QA) standards, ensure models meet the agreed naming protocols, perform evaluations.
	Cross-functional skills	Social skills	Social perceptiveness	Sensitive to the needs of others.
			Coordination	Strong project management and task co-ordination skills, confident in coordinating across multidisciplinary teams, coordination skills, international coordination.
			Negotiation	Negotiates issues with appropriate parties, ability to effectively facilitate contractual discussions and negotiations.
		Complex problem-solving skills	Complex problem-solving	Able to come up with solutions to queries, problem solving abilities, the ability to troubleshoot and solve coordination problems, address and

		resolve the problems.
Technical skills	Operations analysis	Design requirements for filing documents, ability to define, analyze and prioritize business and project requirements, ensure third party requirements.
	Technology design	Invest BIM application design work, BIM technology research and application, management and use of relevant items of equipment, coordination tools, review proposed add-ins and supporting digital tools.
	Equipment selection	Evaluate, select, and apply standard BIM techniques, planning and implementation of BIM technology, evaluate and recommend new architectural/design technologies or computer based systems.
	Installation	Experience with equipment installations, facilities, and utilities design.
	Programming	Familiar with database programming, C # language, ability to write scripts in Python and/or other languages for design tools analysis logic, the person should be able to write scripts and/or code to automate systems.
	Equipment maintenance	Maintain licenses, software, and hardware for department, overseeing and supervising the installation of building systems and specifying maintenance and operating procedures.
	Troubleshooting	Program design and solve technical problems, troubleshooting technology issues, assist troubleshooting and resolving Revit/BIM application issues, resolution of BIM application problems, identify any impact on the BIM coordination program arising from errors in the transmission and use of information during the BIM process.
	Quality controls analysis	Evaluate Mechanical, Engineering, and Plumbing (MEP) as-built drawings and operation and management (O & M) manuals, provide quality control for completeness and adherence to company standards of all MEP drawings produced, overall responsibility for BIM output, model checking and coordination, ability to setup and run clash detection, defining tolerances and checking results, develop skills around checking and quality control of information.
Systems skills	Systems analysis	Maintain office catalog library system including monitoring and logging of all catalogs to ensure they are up to date and in order.
Resource management skills	Time management	Meet deadlines, continually review progress of designs, ensuring key deadlines are met and the project stays on schedule, freely control the project schedule, staffing, cost or budget management, time management, fast-paced team environment with multiple deadlines, work in a timely and efficient manner in an effort to meet design schedule demands.

		Management of financial resources	Financial management of all assigned projects, budget control of the project, accountability in translation of BIM Models aligned with timelines and budgets, the expert ability to identify risks, analyze risks and recommend mitigating controls, work with project managers to schedule work to ensure that projects are completed on time and under budget.
		Management of material resources	Good ability to integrate resources, development of all applications, tools, and functions, coordinate needed hardware upgrades with IT Support.
		Management of personnel resources	Manage CAD/Revit Engineers, proven experience in managing, developing and mentoring a team, ability to manage a team of technicians.
Knowledge	Business and management	Administration/ management	BIM project management, a complete product incubation, design, operation and successful operation experience.
		Clerical	Sets strategy for producing the documents and identifies the sheets planned for each stage of the work, maintain project drawing files, drawing library, and associated records and documentation.
		Economics/ accounting	Broad scope of knowledge of financial services business including products, operations, systems, and organization.
		Sales/marketing	Assist sales with presentation of cost per sales (CPS), the position requires excellent account management skills as well as skills for the whole sales cycle from lead generation to contract closure to ensuring that clients feel they are getting what they signed-up for.
		Customer/personal service	Understanding of the change order management process, client facing experience would be advantageous, experience in client facing coordination and communication, manage package TQ's, request for invitation (RFI)'s and contractors construction advice forms.
		Personnel/human resources	Instructional/teaching experience in CAD/BIM workflows, previous experience of man management within an architectural environment, ability to lead, mentor and develop a team of less experienced BIM coordinators and technicians and support personnel across multiple offices.
	Engineering and technology	Computers/ electronics	Familiar with all types of installation technical standards, norms, can skillfully use related professional software, the use of the Internet thinking, the product is designed to platform-based model and cloud + client + Big Data architecture and layout, understand the basic application, knowledge of BIM software applications, In-depth knowledge of current BIM and virtual design and construction (VDC) software, including but not limited to Autodesk & Trimble products, Demonstrates a working knowledge of X-references, paper/model

			space, plotting, and product data management (PDM) software.
		Engineering/ technology	Evaluate, select, and apply standard BIM techniques, familiar with BIM-related knowledge, heating, ventilation, air conditioning (HVAC), electrical and other related professionals, Building, structure, HVAC, plumbing, electrical engineering BIM structures, BIM understanding.
		Design	Knowledge and familiarity with general planning and code regulations, building design trends, understand design intent, master design standards, knowledge of design trends, working knowledge of design industry workflows, production cycle, and priorities.
		Building/ construction	Extensive knowledge of building materials and construction technology, good knowledge of the curtain wall framing, its material, and installation, familiar building, structural drawings, to have some understanding of the construction process.
		Mechanical	Understanding of current trends in medical equipment and future technology, knowledge of other mechanical trades (sheet metal, plumbing, electrical, maritime), working knowledge of mechanical systems, including design criteria.
		English language	English proficiency.
		Foreign language	Chinese (Putonghua, Cantonese, Mandarin), Japanese, German.
	Law and public safety	Law/government	Code regulations, familiar with all types of installation technical standards, establish China Construction Design International (CCDI), BIM standard, understanding New York State Department of Health (NYDOH), New Jersey Department of Community Affairs (NJDCA), New Jersey Department of Health (NJDOH) codes and procedures, strong understanding of the National Electrical Code (NEC), knowledge of the Office of Statewide Health Planning and Development (OSHPD) procedures, BIM Execution Plan and International Continence Society (ICS) 11.1 standards, an understanding of British Standard (BS) 1192 and PAS 1192, understand and work to space management principles QA standards.
	Communications	Telecommunications	Displays a basic understanding of lighting, electrical, and data/ communications layouts.
		Communications/ media	Profibus, Foundation Fieldbus, SCADA, and Ethernet.
	Transportation		Preferred experience in underground railways.
Education	Education level in specific subjects	Technical vocational	The architectural, structural, mechanical and electrical and other professional, mechanical or structural engineering, plumbing, HVAC, electrical and other related majors, civil engineering, drainage and another related

					undergraduate.
			Business vocational		Real estate, finance, economics, accounting, business management, MBA.
			Computer science		Computer-related professional background, IT related.
			Arts		Design
	Experience requirements	Experience and training	Related work experience		
		Licensing	License, certificate, or registration required		Driver's license, full UK driving license, licensed PE in NYS, licensed PE in NYS/ LEED AP certification.
			Specific license or certificate required	Post-secondary degree	College, Bachelor (BA), Higher National Certificate (HNC), Higher National Diploma (HND), Royal Institute of British architect (RIBA) Part I or equivalent.
				Graduate degree	MS, MA/Ph.D.
				On-the-job training	European Institute of Innovation and Technology (EIT) preferred.
				Character references	Candidates with awarded projects are preferable.
Occupational require-ments	Generalized work activities	Information input	Looking for and receiving job-related information	Getting information	Preparation of information, obtain critical design information, capture agreed on key performance indicators (KPI) data.
				Monitor processes, materials, or surroundings	To manage and maintain a fully coordinated 3D CAD model ensuring all information is up to date and correct, ensure all stakeholders are in alignment with the BIM protocol, monitors the design process, ensure that company procedures and processes are followed.
			Identify/evaluating job-relevant information	Identifying objects, actions, and events	Site surveys and provide written observation narratives, obtains responses to requests for clarification from contractors and keeps a log of such requests, communicates needs to project managers to aid in retrieval of information vital to the project setup process, demonstrated experience with the assembly, collation, and dissemination of construction and engineering information.
				Inspecting equipment, structures, or material	The expert ability to identify risks, analyze risks and recommend mitigating controls, discover, evaluate, lead resolution of and track conflicts and issues with the coordination team, apply judgment, evaluating for best approach, and make decisions with respect to drawings and input interpretation.
				Estimating the quantifiable characteristics of products, events, or information	Size and specify mechanical equipment, experience in running HVAC loads and energy modeling with carrier hourly analysis program (HAP) software preferred, performs more common basic design/engineering calculations.
		Mental processes	Information/data processing	Judging the qualities of things, services, or people	Forecast long-term resource needs to be based on investment programs, ability to work and manage data in a multi-disciplinary environment, apply judgment, evaluating for best approach, and make decisions with respect to drawings and input interpretation.
				Processing information	Analyzing and charting information, filing documents, arrange

			documentation, organization and development of BIM family libraries.
		Evaluating information to determine compliance with standards	Develops solutions to technical and design problems following established standards, project construction drawings review, responsible for checking model drawings between the professional proofreading.
		Analyzing data or information	Research in the field of BIM.
	Reasoning/decision making	Making decisions/ solving problems	Make timely decisions using sound and accurate judgment while keeping appropriate people informed in the decision process, address and resolve the problems, audit, identify and resolve opportunities around model-management to optimize performance.
		Thinking creatively	Design phases (SD, DD, CD), complete regular design work independently, creating and maintaining BIM models, involved in the project BIM design-related work.
		Updating/using relevant knowledge	Increase knowledge and exhibit ability to learn and apply new skills, new technologies and developments in relation to BIM.
		Developing objectives/ strategies	Sets strategy for producing the documents and identifies the sheets planned for each stage of the work, ability to think of big picture.
		Scheduling work and activities	Plan, develop schedule, in charge of arrangements for the professional development of the design schedule, establish BIM model based on construction plans.
		Organizing, planning, and prioritizing work	Organize and prioritize work activities, skilled in prioritizing, organization and time management, prioritize and plan to deliver agreed objectives.
Work output	Performing complex and technical activities	Interacting with computers	Utilizing CAD/BIM, sets up project team software parameters and manages standards, ability to use Revit, experience in running HVAC loads and energy modeling with Carrier HAP software preferred.
		Drafting, laying out and specifying technical devices, parts, and equipment	Lead the development of design and construction documents, project planning and design and construction drawings for integrated management, BIM visual design/BIM for sustainable design, 2D and 3D design and illustration.
		Repairing and maintaining mechanical equipment	Have responsibility for plotting systems including maintenance, ordering of plotter paper and cartridges.
		Documenting/recording information	Maintains CAD library and file system, strategy for producing the documents and identifies the sheets planned for each stage of the work, define data files and elements in BIM, sets strategy for producing the documents and identifies the sheets planned for each stage of the work, electronically filing, organizing, and keeping all drawings and all other forms of paperwork that you may receive or produce up to date.

		Interacting with others	Communicating and interacting	Interpreting the meaning of information for others	Manage and distribute coordinated digital documents to the project team.
				Communicating with supervisors, peers, or subordinates	Continually interact with the client, excellent ability to liaise directly with our clients at high level, coordinate all BIM logistics, data, revisions, metrics, and reporting to senior teams.
				Communicating with persons outside organization	Represent the studio.
				Establishing and maintaining interpersonal relationships	Interacts well with other disciplines and clients in a manner that builds productive relationships, sharing software, download of documents, responsible with customers, such as design institute, electromechanical consultants.
				Selling or influencing others	Consultancy-based technology marketing.
				Performing for or working directly with the public	Promotion 5D BIM technology applications, work with end users, hospital administrators, and consultants.
			Coordinating, developing, managing, and advising	Coordinating the work and activities of others	Collaborate and coordinate with design, construction management, and other disciplines to deliver a fully coordinated BIM model, BIM design process optimization and coordination and cooperation with relevant professional.
				Developing and building teams	Manage designers, manages, and coordinates project team and contractors in communicating directives and ensuring the project scope are built according to plans, specifications, and cost limits.
				Training and teaching others	Train project team members in the management and use of electronic construction information, develop training materials, perform informal BIM training, education, and support to other construction personnel.
				Guiding, directing and motivating subordinates	Work with director to update and enhance current standards, standard setting, development and follow-up.
				Coaching and developing others	Mentor developing talent, over-the-shoulder training, developing and shadowing to staff.
				Provide consultation and advice to others	Mentors less experienced BIM/CAD personnel and offers advice and knowledge, mentoring junior team members.
			Administering	Performing administrative activities	Budgeting, scheduling, and contracting procedures, electronically filing, organizing, and keeping all drawings and all other forms of paperwork that you may receive or produce up to date.
				Staffing organizational Units	Seeking senior cad designer for position with engineering and design firm, prepare for production team.
				Monitoring and controlling resources	Financial management of all assigned projects, negotiates with contractors to achieve a fair and reasonable cost for change orders and reviews their impact on the project.
Occupational	Organizational context	Organizational structure	Decision-making system	Have control over unit or department	Project management, control project, leading team.

require-ments		Have influence over decisions	Confirm graphical integrity of model generated documents by producing and reviewing routine prints to ensure proper line weights, etc., decision quality.
		Monitor data on quality/costs/waste/etc.	Develop and monitor the architectural BIM model, ensure every project has sufficient BIM process oversight, oversee BIM leadership and model management for the studio.
		Determine workflow or order of tasks	Assign project tasks to the instrumentation and control (I & C) project team as required on a project, monitors the design process from conceptual phase through construction administration, ensuring the design idea is consistent and properly executed.
		Invest in new equipment and technology	Better integrate various tool-platforms by establishing workflows for file format exchanges, implementation, and roll out of new versions of BIM application software.
		Develop new products, services, and procedures	Identify and implement processes and practices to strengthen business continuity, develop process to track and analyze BIM efforts on a project.
	Skill variety	Variety of tasks required	Diversity of project, you will gain an experience of working on a wide and varied portfolio of projects, the role will work across various sectors.
	Autonomy	Chance for initiative and judgment	Own initiative and work without excessive supervision.
		Opportunity for independence and freedom	Ability to work independently, independent judgment, ability to independently manage multiple projects.
	Feedback	After finishing job, know own performance	Self-check, evaluate independently, a good level of experience of operating within QA systems under self-direction, you will be expected to check and review your own outputs.
	Individual goal	Achieve most important individual goal	You will gain an experience of working on a wide and varied portfolio of projects which will enhance your skills and test your technical knowledge.
	Role overload	Too much for one person to do	Workload, practical work hard, hard work, ability to work overtime is desirable.
	Organizational values	Fairness/justice	Good work ethic and maintain high company standards with self and others.
		Precision	Careful and precise, must be detail-oriented, attention to detail.
		Stability	Strong employment stability.
		Getting things were done	Decision making, the ability to work in a fast-paced, challenging environment.
		Innovation	A track record of developing forward-looking and innovative approaches, leading by example to achieve sector goals and championing a quality, innovative, and entrepreneurial culture.
		Aggressiveness	Serious and rigorous.
		Valuing customers	Strong sense of service, ability to work in a cost effective, customer focused, team-based environment.
		Providing high-quality products	Good professional quality, excellent ability to liaise directly with our clients at a high level, an eye for detail and a

					strong commitment to quality, responsible for the quality
	Work context	Body positioning	Time spent in body positions	Spend time sitting	95% of work day is sitting, the ability to sit and work with a computer for 8 + h a day.
				Spend time climbing ladders, scaffolds, or poles	Ability to visit job construction areas and climb stairs.
				Spend time kneeling, crouching, stooping, or crawling	Frequently stands and bends.
				Spend time using your hands to handle, control, or feel objects, tools, or controls	Ability to work at a computer terminal with mouse and keyboard for several hours per day, hands and arms - constant use of hands and fingers for mouse, keyboard.
				Spend time bending or twisting the body	Bending or twisting – minimal.
Occupation-specific information	Tasks				For example, a technical coordinator sets up project team software parameters and manages standards.
	Tools and technologies				BIM, Navisworks, Revit, Solibri model checker, ArchiCAD, MS office, Photoshop, FabricationCAD (MEP).
	Title				BIM manager, BIM coordinator, BIM project manager, leader, architect, BIM engineer, technician, BIM designer.
	Description				BIM coordinator reports to and receives direction from Hoffman's BIM manager and the various project-level management teams.

Appendix 2
Required competencies comparison by BIM jobs.

O*NET					BIM project manager	Director	BIM coordinator	Senior architect	BIM manager	BIM designer	BIM MEP coordinator	BIM technician
Level 1	Level 2	Level 3	Level 4	Level 5								
Work characteristics	Abilities	Physical abilities			–	–	7%	–	2%	3%	5%	–
		Sensory abilities	Visual abilities	Visual color discrimination	–	–	7%	–	2%	–	5%	–
	Interests	Occupational interests	Investigative		7%	8%	4%	–	4%	3%		4%
		Work value	Recognition	Advancement	–	–	–	–	4%	–	–	–
				Recognition	–	–	–	–	–	–	–	4%
				Authority	–	–	–	–	2%	7%	–	–
			Independence	Creativity	–	–	–	–	–	1%	–	–
				Responsibility	7%	8%	7%	–	2%	12%	5%	12%
	Work styles	Achievement orientation	Achievement/effort		–	17%	7%	14%	4%	5%	16%	16%
			Persistence		7%	8%	–	7%	8%	7%	–	–
			Initiative		7%	–	15%	–	12%	4%	26%	20%
		Social influence	Leadership		20%	25%	4%	–	17%	9%	21%	4%
		Interpersonal orientation	Cooperation		13%	33%	43%	42%	38%	39%	–	60%
			Concern for others		7%	–	–	7%	2%	3%	–	8%
		Adjustment	Stress tolerance		–	–	7%	5%	2%	5%	5%	12%
			Adaptability/flexibility		7%	8%	4%	–	2%	–	–	8%
		Conscientiousness	Attention to detail		–	–	15%	–	4%	14%	11%	8%
			Integrity		–	–	–	7%	2%	1%	–	4%
		Independence			7%	17%	15%	–	10%	9%	5%	12%
		Practical intelligence	Innovation		–	8%	–	14%	6%	5%	–	8%
			Analytical thinking		–	–	4%	–	4%	1%	5%	–
Worker requirements	Basic skills	Content	Active listening		–	–	4%	–	2%	–	–	–
			Writing		7%	–	22%	23%	15%	12%	16%	4%
			Speaking		27%	25%	33%	21%	40%	24%	42%	32%
			Mathematics		7%	–	4%	–	–	1%	5%	–
		Process	Critical thinking		–	–	–	–	2%	–	–	–
			Active learning		–		4%	–	8%	7%	11%	8%
			Learning strategies		–	8%	4%	–		3%	–	4%
			Monitoring		7%	8%	15%	7%	15%	4%	11%	20%
		Social skills	Coordination		7%	8%	4%	7%	2%	11%	–	4%
			Negotiation		–	–	–	7%	4%	1%	5%	–
		Complex problem solving skills	Complex problem solving		–	–	–	–	4%	5%	11%	4%
		Technical skills	Operations analysis		–	–	–	7%	2%	1%	–	4%
			Technology design		–	–	28%	7%	21%	14%	11%	8%
			Equipment selection		–	–	4%		17%	11%	5%	–
			Installation		–	–	4%		2%	–	5%	–
			Programming		–	8%	–		4%	1%	–	–
			Equipment maintenance		–	–	4%		12%	1%	–	–
			Troubleshooting		–	–	11%		6%	1%	–	–

			Quality control analysis		7%	17%	26%		13%	–	16%	12%
		Systems skills	Systems analysis		–	–	–	–	4%	–	–	
		Resource management skills	Time management		13%	17%	19%	–	15%	8%	42%	44%
			Management of financial resources		7%	–	4%	14%	8%	3%	–	–
			Management of material resources		–	8%	–	7%	4%	–	–	4%
			Management of personnel resources		27%	–	–	–	15%	8%	11%	–
	Knowledge	Business and management	Administration/management		7%	17%	4%	–	6%	5%	16%	–
			Clerical		–	–	7%	–	8%	–	–	12%
			Economics/accounting		–	–	–	–	2%	–	–	–
			Sales/marketing		–	–	–	–	–	1%	5%	–
			Customer/personal service		–	8%	–	14%	2%	–	11%	4%
			Personnel/human resources		–	8%	–	7%	8%	1%	–	–
		Engineering and technology	Computers/electronics		7%	33%	26%	–	23%	9%	11%	–
			Engineering/technology		33%	25%	22%	21%	27%	50%	58%	44%
			Design		20%	33%	33%	57%	33%	24%	42%	32%
			Building/construction		7%	8%	11%	7%	13%	30%	53%	8%
			Mechanical		–	–	15%	–	8%	4%	21%	16%
			English language		33%	–	7%	50%	6%	20%	–	8%
			Foreign language		27%	25%	7%	–	2%	18%	5%	–
		Law/public safety	Law/government		33%	8%	33%	–	21%	19%	21%	16%
		Communications	Telecommunications		–	–	–	–	–	–	–	4%
			Communications/media		–	–	–	–	2%	1%	–	–
		Transportation			–	–	–	–	2%	–	–	–
	Education	Education level in specific subjects	Technical vocational		60%	42%	30%	21%	25%	39%	37%	44%
			Business vocational		7%	–	–	–	–	1%	–	–
			Computer science		–	8%	–	–	–	3%	–	–
			Arts		–	–	4%	–	–	1%	–	4%
	Experience requirements	Experience and training	Related work experience		73%	83%	52%	57%	52%	72%	47%	40%
		Licensing	License, certificate, or registration required		33%	33%	4%	7%	6%	14%	26%	4%
		Specific license or certificate required	Post-secondary degree		47%	67%	37%	–	33%	64%	21%	48%
			Graduate degree		33%	–	4%	–	6%	5%	–	4%
			On-the-job training		–	–	–	–	–	1%	–	–
			Character references		–	–	–	–	–	1%	–	–
Occupational requirements	Generalized work activities	Information input	Looking for and receiving job-related information	Getting information	–	–	4%	–	2%	1%	–	8%
				Monitor processes, materials, or surroundings	20%	8%	4%	–	8%	3%	11%	16%
			Identify/evaluating job-relevant information	Identifying objects, actions, and events	7%	–	15%	–	4%	3%	–	–
				Inspecting equipment, structures, or material	–	8%	7%	–	12%	1%	11%	8%
				Estimating the quantifiable characteristic of products, events, or information	–	–	–	–	2%	4%	16%	–
		Mental processes	Information/data processing	Judging the qualities of things, services, or people	–	–	–	14%	8%	–	–	4%
				Processing information	7%	–	7%	7%	2%	3%	5%	4%
				Evaluating information to	20%	33%	37%	36%	29%	11%	37%	44%

		determine compliance with standards								
		Analyzing data or information	13%	8%	4%	–	–	3%	–	–
	Reasoning/ decision making	Making decisions/solving problems	13%	–	7%	29%	15%	8%	5%	16%
		Thinking creatively	20%	33%	22%	29%	21%	30%	21%	52%
		Updating/using relevant knowledge	–	8%	7%	–	2%	3%	–	4%
		Developing objectives/ strategies	7%	17%	4%	7%	15%	1%	–	4%
		Scheduling work and activities	13%	25%	19%	14%	19%	8%	21%	8%
		Organizing, planning, and prioritizing work	20%	8%	26%	7%	17%	5%	16%	12%
Work output	Performing complex and technical activities	Interacting with computers	67%	83%	81%	64%	77%	72%	84%	84%
		Drafting, laying out, specifying technical device, parts, equipment	20%	42%	63%	43%	48%	59%	47%	76%
		Repairing, maintaining mechanical equipment	–	–	–	–	2%	–	–	–
		Documenting/recording	13%	17%	44%	21%	40%	7%	26%	40%
Interacting with others	Communicating and interacting	Interpreting the meaning of information for others	–	–	–	–	4%	–	–	–
		Communicating with supervisors, peers	13%	25%	26%	–	31%	15%	26%	32%
		Communicating with outside persons	–	8%	–	–	–	–	–	4%
		Establishing, maintaining interpersonal relationships	47%	42%	44%	50%	48%	30%	53%	48%
		Selling, influencing others	–	–	–	–	–	–	5%	–
		Performing for or working with the public	13%	–	4%	–	6%	4%	11%	–
	Coordinating, developing, managing, and advising	Coordinating the work and activities of others	33%	–	15%	7%	13%	23%	16%	24%
		Developing and building teams	13%	8%	4%	14%	38%	1%	5%	8%
		Training and teaching others	13%	–	26%	–	42%	9%	21%	20%
		Guiding, directing, and motivating subordinates	27%	25%	48%	–	44%	5%	21%	16%
		Coaching and developing others	13%	25%	–	7%	8%	–	–	–
		Provide consultation and advice to others	20%	33%	26%	29%	25%	23%	32%	16%
	Administering	Performing administrative activities	20%	8%	22%	–	13%	12%	21%	8%
		Staffing organizational units	–	–	–	7%	10%	1%	5%	–
		Monitoring and controlling	7%	–	–	–	2%	3%	–	–

				resources								
Occupational require-ments	Organizational context	Organizational structure	Decision-making system	Have control over unit or department	20%	25%	4%	–	17%	4%	16%	–
				Have influence over decisions	7%	–	–	7%	2%	–	–	–
				Monitor data on quality/ costs/waste/etc.	13%	25%	41%	21%	42%	5%	42%	28%
				Determine workflow or order of tasks	7%	25%	15%	–	25%	4%	11%	4%
				Invest in new equipment and technology	–	8%	7%	–	6%	–	–	–
				Develop new products, services, and procedures	–	25%	11%	–	17%	1%	–	4%
			Skill variety	Variety of tasks required	7%	–	–	–	–	1%	–	4%
			Autonomy	Chance for initiative and judgment	7%	8%	4%	–	4%	–	–	4%
				Opportunity for independence freedom	7%	25%	15%	–	10%	9%	–	4%
			Feedback	After finishing job, know own performance	–	–	7%	–	2%	3%	5%	8%
			Individual goal	Achieve most important individual goal	–	–	–	–	2%	–	–	–
			Role overload	Too much for one person to do	13%	–	4%	–	4%	9%	5%	4%
			Organizational values	Taking chances; going out on a limb	–	–	–	–	–	–	–	4%
				Fairness/justice	–	–	–		2%	–	–	0%
				Precision	–	–	–		2%	5%	5%	4%
				Stability	–	–	–		–	–	5%	0%
				Getting things done	7%	–	4%		–	1%	–	0%
				Innovation	–	8%	–		2%	–	–	0%
				Aggressiveness	7%	–	–		–	–	–	0%
				Valuing customers	7%	–	4%	7%	2%	–	5%	4%
				Providing high quality products	7%	–	19%	14%	10%	11%	21%	20%
	Work context	Body positioning	Time spent in body positions	Sitting	–	–	7%	–	–	–	–	–
				Kneeling, crouching, stooping	–	–	4%	–	–	–	–	–
				Using your hands to handle	–	–	4%	–	–	–	5%	–
				Bending or twisting the body	–	–	4%	–		–	–	–

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