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Article

Competence-Targeted Education for BIM Professionals: A Case Example of the Vietnamese Construction Industry

Tuan Anh Nguyen

National University of Civil Engineering, Hanoi, Vietnam
E-mail: anhnt3@nuce.edu.vn (Corresponding author)

Abstract. The adoption of Building Information Modelling (BIM) in the construction industry has grown substantially worldwide, and in Vietnam, there was no exception. This creates an increasing need for new BIM professionals that requires specific competencies. Vietnamese educational institutes have made efforts to develop a strategic education plan of incorporating BIM components into their programs in Construction Engineering and Management (CEM). It is crucial to figure out the highly demanded competencies from both the job market and academic requirements. This paper conducts a survey on targeted competencies from current BIM job ads in the Vietnamese construction industry and worldwide systematic literature review. Competency criteria from the two distinct sources were evaluated and compared. The results show that the Vietnamese job ads competencies were reasonably consistent with those of surveyed literature where BIM software skill is must-have competence. The required competencies also include knowledge of BIM concepts and standards, regulations, soft skills, and work behaviours. From these BIM demanded competencies, this paper suggests a system thinking approach to organise, in principle, BIM competence-targeted program, integrating BIM components into the existing/new curricula, taking case example of Vietnam education institutes. The paper may be of interest to anyone who is involved in BIM education.

Keywords: BIM education, construction engineering and management, competence, system thinking, Vietnamese education.

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1. Introduction

Building Information Modelling (BIM) and the adoption of Building Information Model have rapidly gained popularity worldwide, which, in turn, have stimulated the demand for BIM skilled professionals in the field of construction engineering and management (CEM). The impressive growth of the BIM market has resulted in a scarcity of skilled and qualified BIM personnel in the industry. Several studies have discussed the lack of skilled BIM professionals as one of the main hurdles obstructing the BIM implementation in practice [1]–[5].

The development of BIM market creates an increasing need for new BIM professionals. Each demanded job position requires specific competencies. Literature in BIM education focuses on analysing the supply-demand competence relationship between programs offered by universities and needed skills required by industry [1], [3], [6]–[8]. The useful inclusion of BIM components into higher education CEM curricula, hence, absorbs attention from researchers [4], [9]–[15].

Although BIM educators have undertaken significant transformations and have achieved initial improvements, many researchers have criticised educational providers for their lack of schemes and abilities to effectively incorporate and broaden BIM into existing and future CEM programs [1], [2], [16]–[21]. The educational providers might fail to identify targeted-educational output and to organise BIM components into their programs [1], [3], [7]. The involved BIM program varied from construction/civil engineering [2], [4], [5], [9], [18], [22], [23], quantity surveyor (QS) [19], [24], to construction management (PM) [8], [20], [25]–[27].

Generally, BIM practice in Vietnam has been extending significant influence within the construction industry, and this leads to the need for educating/training more professionals held practical BIM knowledge and skills. These competencies are essential for undergraduates in developing their advanced professionals in the competitive job market and meeting their future career targets [8], [18], [24], [28].

The term 'competency', as an output of the education system, is referred to an individual's ability to fulfill a particular task or produce a measurable outcome [3], [7]. BIM competency, here in this paper, is defined as a set of essential requirements for BIM job applicants that allows them to appropriately perform BIM job. Competency may include knowledge, educational background, qualification, licenses, skills, and experience [3], [4], [29].

Agreed with findings from Nguyen and Nguyen [30], it is shown that BIM teaching level in Vietnamese universities and educational institutes, in the field of CEM, is generally remaining at 'Aware', according to the BIM teaching impact matrix developed by BIM Academic Forum, UK [31]. This level indicates that BIM is a potential research and teaching area but should not significantly affect the way universities teach. Undergraduates should be aware of BIM and its impact on their career futures. Researchers/lecturers do need an understanding of BIM concepts and standards, and the way BIM impacts the industry. For curriculum, key BIM modules are generally identified, and BIM knowledge is incorporated optionally. This creates the need for restructuring their curricula, aiming at incorporating more BIM components, and reaching the next level, 'Infused' [31]. A curriculum in this 'Infused' level identifies the impact of BIM in all areas, but the BIM use is still limited. As a result, students should have the opportunity to study BIM knowledge and application in a particular discipline and multi-discipline context [31]. Besides, reaching the 'Infused' level is logically necessary for keeping pace with the Vietnamese government's BIM utilization proposal [32].

It can be shown that, in order to develop BIM education and training in the Vietnamese education context, the two recent outstanding questions must be answered as follows:

- What are the required competencies of BIM jobs in the Vietnamese construction labour market?
- How can Vietnamese universities/educational institutes develop an overall strategic plan to integrate the BIM-related knowledge components into their existing/new CEM programs?

Regarding the first question, this paper conducts a survey on BIM-related job posting in the leading online job advertising websites in the Vietnam construction labour market. These data are then analysed based on statistical analysis. The focus of the survey is on junior and/or pre-senior positions which are at their early/mid-careers, and from that, the suggestions on BIM education program of bachelor's degree (undergraduate level) are provided, based on system thinking. The majors may include any academic disciplines, such as general civil/ building engineering, and/or construction economics and management. The finding from the survey on BIM competencies is potential, providing suitable answer for the first question and incorporating into the answer for the second question.

Concerning a relatively adequate answer for the second question, the paper applies system thinking, in principle, to develop a strategic plan for designing BIM programs, integrating BIM components into the existing/new CEM courses. In the paper, system thinking is highly suggestive and useful for developing BIM programs tailored for any strategic educational goals.

The structure of the paper is presented as follows. First, the background of the research topic related to competence-based BIM education and system thinking is given. The literature survey process in this paper is based on that suggested in Bearman et al. [33]. Section 3 and 4 demonstrate the research survey method and result, respectively. From that, in Section 5, the paper provides evaluation and comparison of competency criteria from the distinct sources, the surveyed results and the reviewed literature. Section 5 also suggests system

thinking, in principle, in competence-based BIM education and analyses the usefulness of control system theory for planning BIM courses. Finally, the paper's contributions to the body knowledge and practice have been given in the conclusion.

2. Background

2.1. Competence-based BIM Education

Related to the paper's work, previous studies from Wu and Issa [1], Uhm et al. [3], Lee et al. [25], Succar et al. [7], and Barison and Santos [29] focused on establishing demanded competencies of BIM jobs in specific CEM job titles.

Wu and Issa [1] noted that there was a cyclic relationship between the BIM education and the BIM job market, and the study findings derived from the online BIM job ads survey have considerable implications for BIM training, education, and employment. The authors emphasised that the collaboration between BIM headhunters and BIM educators is inevitable and necessary to satisfy the rising market demand of BIM professionals.

Uhm et al. [3] surveyed 242 online BIM-related job ads from the US, UK, and China, and identified 8 types of BIM professionals by analysing job position and role of the 35 surveyed job titles. This study also analysed 43 competencies, deriving from the job postings, and categorised into three types: must-have, typical, and job-specific competencies. This finding provides potential guidelines for BIM educators and companies in training and recruiting BIM professionals in the construction industry.

Targeted BIM industry experts in the US in 2012, Lee et al. [25] carried out an online survey on BIM education outcomes demanded by selected construction firms in the labour market. The result showed that competencies, including the conceptual understanding of BIM standards, BIM management, and BIM software application skills, were highly demanded in the surveyed industry. The authors also suggest that BIM institutes should bring their BIM incorporated courses up to date to change in line with the industry practices and trends.

Succar et al. [7] introduced conceptual models to elucidate how individual BIM competencies can be categorised, filtered, and aggregated into a seed competency inventory. The targeted competencies include core (qualifications and licences, and foundational traits), domain (design, management, analysis, and planning), and execution (software tools, and techniques). The paper also discussed the benefits of incorporating those designed BIM competencies in BIM courses for industry and academics.

Barison and Santos [29] made a comparison of competencies needed for a BIM manager/coordinator from BIM job descriptions and surveyed in the selected literature. The result showed that both surveyed sources of the required competencies for a BIM coordinator, despite different focuses, were generally in agreement. However, the paper focused only on BIM manager and coordinator job applicants in the US, and could not expand the finding related to the competencies of other BIM specialists.

To sum up, the previously mentioned papers emphasised the necessity for collaborating between BIM educators and BIM practitioners. This collaboration should focus on analysing the supply-demand competence relationship between programs offered by universities/institutes and the needed skills required by industry in all job positions. Although the needed competencies in BIM job ads and literature were demonstrated neatly in detail, there was still a lack of direct comparison between construction/civil engineering and consultant (Quantity Survey QS, Project Management PM) job groups. That is presented in this paper.

2.2. System Thinking

A system is referred to as an input-output transformation [34], [35]. All systems are characterised by their inputs and outputs. Inputs can be classified as influenceable (referred to as controls) and uninfluenceable ones. Outputs illustrate a system's performance, behaviour, or response, and they are measurable and observable. With a changing external environment, the systems are influenced by involved uncertainty, impact factors, or disturbance [36]–[38].

Regarding the application of control system thinking in education and engineering problem solving, there were outstanding research works from [34]–[37], [39], [40]. Blockey [40] illustrated the specific interpretation of systems thinking introduced at the University of Bristol for a thirty-year duration. Godfrey et al. [35] emphasised systems thinking is not merely an engineering approach; instead, it is needed to tackle many practical problems, especially education. Brown and Elms [37] provided a checklist for the guidance of decision making in a complex context, based on the idea of understanding the system, contributing towards improving the quality of civil engineering practice and education. Elms and Brown [36] proposed major types of engineering models and their purposes with respect to system thinking. Carmichael [34], [39] introduced essential concepts extracted from control systems theory and illustrates their potential application in thinking about engineering practices and education.

Although system thinking has been developed in many areas, the literature of BIM education still lacks its adoption. Adapted from the above studies, the paper demonstrates the usefulness of system thinking and applies control system theory, in principle, [34], [37], [38] for establishing BIM programs of universities or BIM institutes, incorporated survey on demanded competence of the construction labour market. This is unavailable in BIM education literature.

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3. Research Survey Method

The paper analyses BIM jobs and their competencies based on the three-step procedure presented in Fig. 1.

In the beginning, the paper collected information of BIM-related jobs via major online job ads websites. Next, the result is analysed and classified into categories, such as roles, positions, locations, business types. Finally, a set of demanded competencies is illustrated for each target BIM job.

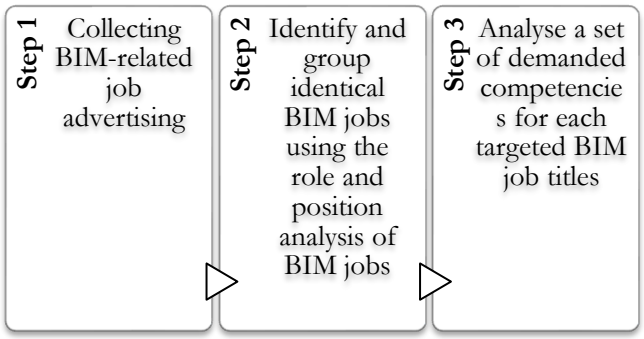

Fig. 1. Research survey procedure.

The in-depth illustration of the survey method is provided as follows. In the first step, online job ads were investigated and collected from web search engines, which were posted in four major job ads websites in Vietnam, namely vietnamworks.com; vn.indeed.com; careerbuilder.vn; and 123job.vn. Searching on each job website, the used keywords included 'BIM', 'Building Information Modeling', 'Building Information Model', 'Virtual design and construction', 'VDC', 'BIM Quantity Surveyor', 'BIM QS', ' BIM Project Manager', 'BIM PM', 'BIM Computer-Aided Design', 'BIM CAD', and 'BIM Revit' for three months from July to September 2020. The used keywords and posted job ads are written both in Vietnamese and in English. A total of 164 online job ads for BIM-related professionals were summarised from these four primary job postings sources. However, 46 of them were virtually identical and then eliminated, so this makes a total of 118 posting positions have proceeded for the second step.

In the second step, the posted ads were analysed and classified into groups, based on the geographical distribution (locations), stakeholders (consultant, contractor or owner), job titles (manager/coordinator, designer/technician, and consultant (quantity surveyor QS/project management PM). The proportions of these groups were calculated accordingly. BIM manager and/or coordinator (T1) was referred to as manager and/or coordinator of major work components and tasks: CAD, Revit, VDC, and others. Some main job descriptions, such as BIM architectural and structural designers, engineers, technicians, may be considered as virtually similar and were grouped together as job titles BIM designer and technician (T2). In contrast, BIM consultant group (T3) includes professionals on quantity surveyor (QS) and/or general construction/project management (PM).

Finally, a set of demanded competencies for each targeted job post was analysed. Key/common/essential or significantly occurring competencies required for collected posts are pointed out and presented in BIM job competencies analysis. The paper summarised eight essential or significantly occurring competencies from posted ads and intentionally investigated the current demand for an additional competence. Those highly demanded competencies, with the percentage over 60% of total job posts, are about (G1) application skills of BIM software; (G2) knowledge of BIM concept and standard; (G3) understanding of BIM-related laws and regulations; (G4) BIM or general working experiences; (G5) professional knowledge (construction and estimation); (G6) soft skills (creative thinking, collaboration; independence, adaptability); (G7) English and/or other languages; (G8) work behaviours (responsibility, credibility, discipline, and flexibility). In addition, the extra competence analysed on purpose is (G9) knowledge of Green or LEED or Sustainable BIM. By that way, the paper covers all highly required competencies (from G1 to G8) in the BIM labour market and discovers the targeted one G9.

4. Survey Result

The geographical distribution of posted ads was presented in Fig. 2. The significant proportion (41%) of the collected job ads was from Ho Chi Minh City - the biggest and most high-tech city in Vietnam - followed by Hanoi - the capital - (29%) and other cities (30%).

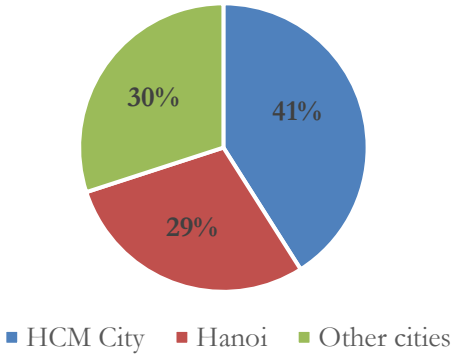

Fig. 2. Geographical distribution of posted ads.

Based on stakeholder classification, presented in Fig. 3, while consultant firms have been highly demanding BIM professionals, accounted for 52% of total ads posts, contractors and owners have been seeking only 29% and 19% of total posted job positions.

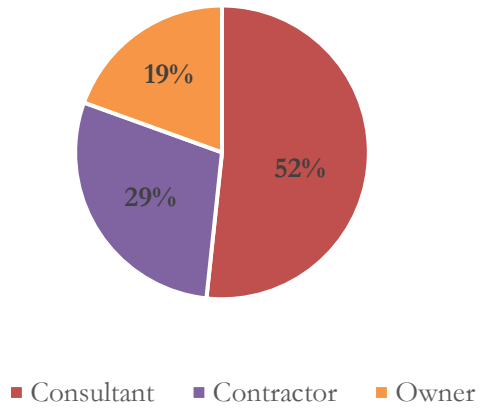

Fig. 3. Stakeholder distribution of posted ads.

Figure 4 illustrates the three major targeted BIM job titles in the survey. BIM manager/coordination accounted just for 18% of job online posting, while BIM designers and technicians were sought significantly on the Vietnamese construction job market with 55% of collected job ads. BIM consultant, including quantity surveyor (QS) and general construction/project management (PM) job titles, was required mostly one-third of the total surveyed labour market demand.

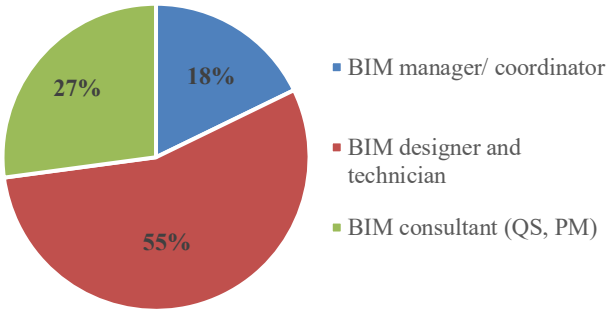

Fig. 4. Target BIM job title groups.

BIM job competency analysis is presented in Table 1. Application skills of BIM software (G1) is the most demanding competence, almost 100% job description required, in the BIM labour market for the targeted job title groups T1, T2, and T3. While nearly two-thirds of all posts of each job titles required knowledge of BIM concept and standards (G2), understanding of BIM-related law and regulations (G3) were required more often for the manager/coordinator (T1) and consultant (T3) than for the design and technician (T2).

Regarding working experience (G4), manager/coordinator demanded much more work experience (with 100% of job posts required 3-5 years) than designer/technician and consultant QS/PM did (with 58.5% and 81.3%).

Table 1. BIM competency in targeted job titles.

No	Competencies	BIM Job titles		
		Manager/ coordinator T1	Designer/ Technician T2	Consultant (QS, PM) T3
G1	Application skills of BIM software	95.2%	100.0%	100.0%
G2	Knowledge of BIM concept and standards	76.2%	73.8%	68.8%
G3	Understanding of BIM-related law and regulations	85.7%	63.1%	90.6%
G4	BIM or general working experiences (3-5 years)	100.0%	58.5%	78.1%
G5	Professional knowledges (construction, estimation)	85.7%	70.8%	84.4%
G6	Soft skills (Creative thinking, collaboration, independence, adaptability)	90.5%	83.1%	71.9%
G7	Professional English and/or other languages	71.4%	63.1%	87.5%
G8	Responsibility, Credibility, Discipline, Flexibility	61.9%	69.2%	81.3%
G9	Knowledge of Green/ LEED/ Sustainable BIM	4.8%	7.7%	6.3%

Based on a statistical analysis of job ads, the paper made a further calculation on average years of required working experience among those three job titles, including BIM manager/coordinator (T1), BIM designer and technician (T2), and BIM consultant (including professionals on Quantity Surveyor (QS) and general construction/project management (PM) (T3)). Figure 5 shows the required working experiences of T1, T2, and T3 were approximate 7.4, 3.2, and 4.3 years, respectively. Those results are intuitive as the BIM manager/coordinator job title sought potential candidates having more experienced than BIM designer/technician and BIM consultant did. BIM designer/technician position, on the other hand, looked for early-career applicants.

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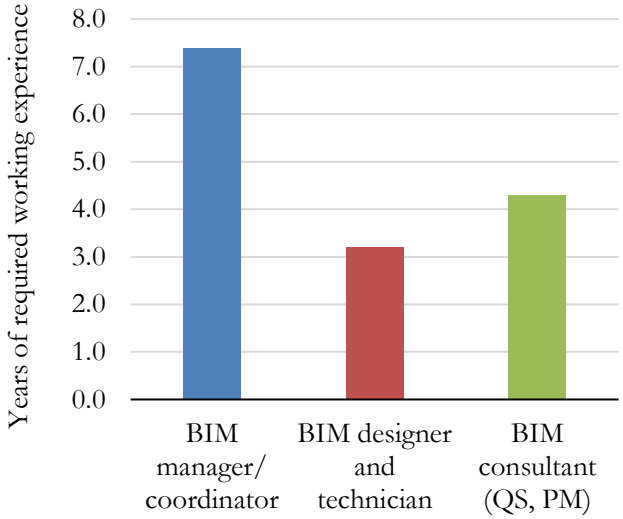

Fig. 5. Required working experience of three targeted job titles.

Besides, professional knowledge in construction and estimation (G5) and soft skills (G6), such as creative thinking, collaboration, independence, adaptability, were also highly demanded from the construction industry. Languages skills (G7) and working behaviours (G8), namely responsibility, credibility, discipline, flexibility, were considered generally as optional competence, which provided competitive advantages for job applicants who own them.

Knowledge of Green/ LEED/Sustainable BIM (G9) is an extra competence deliberately added to competency analysis to investigate its demand in the construction labour market. It is shown that the demand for this competence is still in its infancy, indicating only a few percentages of job descriptions required in all job titles groups.

Figure 6 shows graphically comparison of highly required competency in each targeted job title groups.

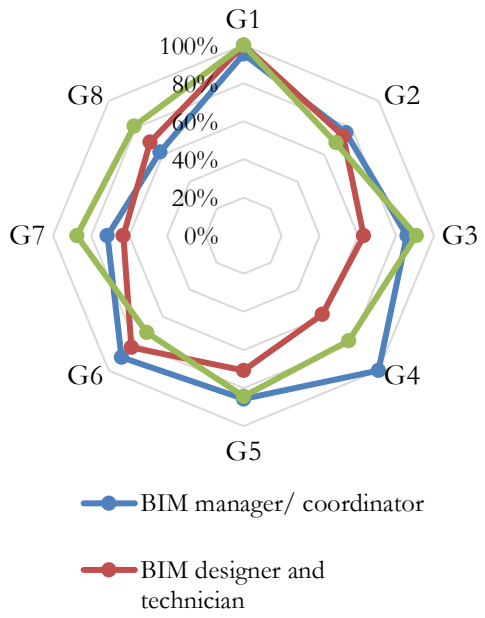

Fig. 6. Competency among three targeted job titles.

As mentioned above, all job descriptions (Fig. 6) required BIM software skills. In addition to that, BIM manager/coordinator (T1) recruiters preferred candidates who had broad BIM or general working experience, in-depth professional knowledge, and practical soft skills. While BIM designer/technician (T2) were strongly required demonstrating competencies of understanding BIM concept and standard and soft skills, BIM consultant (T3) (QS/PM) must have profound understanding of BIM-related laws and regulations, comprehensive construction and estimation knowledge and fluent professional English/foreign language skills.

The above findings are compared to those from [1], [3], [7], [25], [29] in the literature that is demonstrated in the Discussion section. They are critical and provide information on both output and input of the system thinking model for establishing the BIM education program presented below.

5. Discussion

5.1. BIM Competencies

The paper conducts a survey based on online posted job ads from four main websites in the Vietnamese labour market during the recent three-month period. The result draws a comparison of the required competencies of three job title groups, including manager/coordinator (T1), design/technician (T2), and consultant (QS, PM) (T3). BIM software skill G1 is must-have competence - highly demanded skills in the construction job market - for all job title groups. The required competencies also include knowledge of BIM concepts and standards, regulations G2-3, professional knowledges G5, soft skills G6, and work behaviours G8. In contrast, knowledge in Green/LEED/Sustainable BIM G9 experienced the least consideration of BIM employers.

Compared to findings from [1], [3], [7], [25], [29], the literature generally agrees to name those competencies (BIM software G1, BIM knowledge and regulation G2-3, professional knowledges G5, soft skills G6, and attitudes G8) are essential for BIM jobs; however, their significances slightly differ. The literature shows more interest in professional knowledge and critical thinking (equivalent to G5), while the survey result on the job market is more concerned about technological knowledge and practical skills (BIM software) G1. This finding shows that the Vietnamese job ads competencies were logically/reasonably consistent with those of surveyed literature.

Required competencies presented in the paper are considered as essential or common competencies. Although the analysis of each job-specific competencies is not treated in the paper, the essential or must-have competencies may be considered as fundamental core courses of BIM education. They also can be designed and taught with the targeted level of required knowledge and difficulties. Besides, the analysed BIM job titles and

competence groups may be served as a guideline to recruit or evaluate BIM personnel performance.

5.2. System Thinking on Competence-based BIM Education

As discussed in Section 1, BIM teaching level in Vietnamese universities and educational institutes generally remains at 'Aware', and it is shown that there is a need for developing a systematic approach to incorporate BIM components into existing/new offered programs [30], [31]. System thinking, therefore, provides comprehensive systematic analysis [35], [38], [40], [41] may be useful for dealing with BIM education problems in the Vietnamese construction context.

A broad type of control systems would be as open loop or closed loop [34]. Both types, open loop control and closed loop control, are belong to the synthesis configuration, play an important role in engineering and education practices [36]–[38].

Figure 7 illustrates the idea of open loop control. However, the open loop control (Fig. 7) transfers one-way information and does not allow for follow-up monitoring and correcting control action [39]. Closed loop (or feedback) control, on the other hand, allows circulated transmission of information and facilitates feedback and system correction to proceed [34], [37]. The closed loop control, therefore, may be more suitable for structuring BIM program.

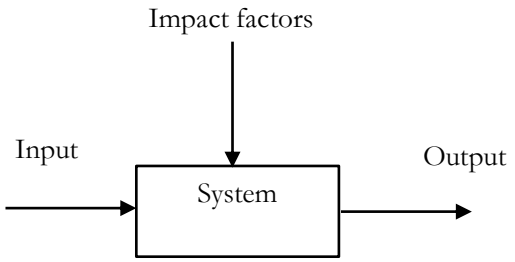

Fig. 7. Open loop control (Adapted from [38], [39]).

Figure 8 shows an example of advanced system thinking using control systems theory for BIM education program, applied in Vietnamese context. BIM program, offered by Vietnamese universities or BIM institutes, is considered as an analysed system, characterised by its input and output, and influenced by disturbance or impact factors. The fundamental configurations would be analysis, synthesis, and investigation [34]; however, the suitable configuration, here applied to establish BIM program, should be investigation (inverse configuration): given input and output, obtain system content.

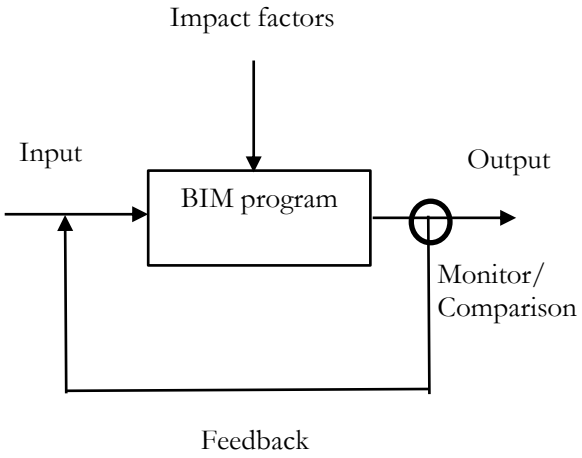

Fig. 8. Closed loop control representation of BIM program (Adapted from [38], [39]).

To start with, measurable and observable outputs that illustrate BIM program performance should be clearly identified by Vietnamese universities or educational institutions. These outputs should be entirely consistent with competence demanded by the job market, referenced as survey results in Section 4, and incorporated educational strategies. Inputs, including controls and uninfluenceable ones, are also given based on the nature of existing programs, BIM training objectives, BIM-targeted competencies and/or Vietnamese national and international targeted education standards. Impact factors or disturbance, for example changes in labour market demand and/or education policies, are uncertainties of the external environment. The existence of disturbance leads to a need for a feedback loop, initiating routine, or regular monitoring/comparison. During the continual monitoring process, Vietnamese education organisers should evaluate the consistency of targeted education outputs, and make necessary adjustments. This also improves the system resilience [39].

System thinking on a competence-targeted BIM program in this paper, based on control systems theory, is suggestive. This can be applied to any BIM program in any academic discipline. The paper initially provides, in principle, the general idea of system thinking application, and it stops short of dealing in-detail with the BIM program planning process. This is considered as a limitation of the paper. More thoughts may be necessarily added to clarify system components, such as inputs, outputs, disturbance, and feedback loop for future research. These variables may change to adapt the system to existing circumstances, but the general idea of system thinking does not.

There were comprehensive studies emphasise the successful adoption/application of system thinking in education [34]–[40]; however, the literature on system thinking has not dealt properly with BIM program and its pedagogy. Future research should highlight convincing

case studies that assist the take-up of the paper's proposal.

6. Conclusion

The substantial growth of BIM application/adoption in the construction industry is creating new professionals. Each position requires specific competencies. It is crucial to figure out the demanded competencies in the labour market, and from that, to develop a strategic education plan of incorporating BIM components into the program. The paper concentrates on the two recent outstanding questions must be answered: (1) What are the required competencies of BIM jobs in the Vietnamese construction labour market? And (2) how can Vietnamese universities/educational institutes develop an overall strategic plan to integrate the BIM-related knowledge components into their existing/new CEM programs? For the first question, this paper conducts a survey on BIM-related job posting in the leading online job advertising websites in the Vietnam construction labour market and compares to the reviewed literature. The finding from the survey on BIM competencies provides a suitable answer for the first question and then incorporates into the answer for the second. In terms of developing a relatively adequate answer for the second question, the paper applies system thinking, in principle, to develop a strategic plan for designing BIM programs, integrating BIM components into the existing/new CEM courses.

To sum up, the paper contributes to the body of knowledge and practice as follows:

- The paper surveys the required competencies from Vietnamese BIM job ads. It is shown that BIM software skill is must-have competence - highly demanded skills in the construction job market - for all job title groups. The required competencies also include knowledge of BIM concepts and standards, regulations, soft skills, and work behaviours.
- The paper compares the surveyed competencies to those demanded from the reviewed literature. The result demonstrates that there was logical/reasonable consistency in competencies from both sources.
- Based on the targeted competencies, the paper originally applies system thinking, in principle, to organise BIM program, integrating BIM components into the existing/new CEM courses. System thinking, presented in the paper, is highly suggestive and useful for developing BIM programs tailored for specific distinct educational goals. This can be applied to any BIM program in any academic discipline.

The finding of the paper may be of interest to anyone who is involved in BIM education.

The future direction of the paper would be taking a deeper survey on BIM competencies, comparing multiple sources, such as job ads, academics, and headhunter interviews, especially considering the impacts of the Covid-19 pandemic.

In addition, as discussed in the Discussion section, the application of system thinking on BIM education, presented in the paper, demonstrates, in principle, the general idea. More thoughts may be necessarily added to clarify system components, such as inputs, outputs, disturbance, and feedback loop. Further study also should highlight convincing case studies that assist the take-up of the paper's proposal.

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Tuan Anh Nguyen is an inspirational and motivated lecturer in the field of construction economics and management. He received the B.S. in civil engineering from the National University of Civil Engineering (NUCE), Hanoi, Vietnam in 2008; the M.S. in financial engineering from the University of Liege, Belgium in 2012; and the Ph.D. degree in civil and environmental engineering from the University of New South Wales, Sydney, Australia in 2019.

From 2009 to 2010, he was a Research and Lecture Assistant with the NUCE. Since 2011, he has been a Lecturer with the Construction Economics Department, NUCE. In 2020, he was promoted to Head of this Department. His research interests include options analysis, risk management, decision-making technique, BIM application and education, Public-Private Partnership, flexible and adaptable infrastructure.