Human-Organization-Technology (HOT) Fit Model for BIM adoption in Construction Project Organizations: Impact factor analysis using social network analysis and comparative case study

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Abstract: The sluggish adoption of Building Information Modeling (BIM) is attributable to various technical, managerial, personnel, procedural, and institutional issues encountered by an organization within which such adoption takes place. However, these issues are under researched from a holistic perspective. Based on a proposed human-organization-technology fit (HOT fit) model, this paper aims to study the impacting factors of HOT fit in BIM adoption within construction project organizations (CPOs). It operationalized the HOT fit of 14 BIM case projects using social network analysis (SNA) methods and investigated how the different factors impact the HOT fit and its three sub-dimensions, i.e., Human-Technology (HT) fit, Organization-Technology (OT) fit, and Human-Organization (HO) fit using comparative case study. It is found that the project size has significantly negative relations with HOT fit, HT fit, and OT fit; while hierarchy steepness has positive correlations with HT fit, OT fit, and HO fit. OT fit is also found to have a weakly negative relationship with BIM level of details (LODs). A joint factor analysis further discloses that flatter the hierarchy, the larger the project size, and the higher the BIM LOD, the more difficult to achieve a high HOT fit, HT fit, or OT fit. Thus, CPOs should use steeper hierarchical structure and take a progressive BIM adoption strategy by adopting from smaller projects and/or lower LODs. This research empirically examined how project organizational and technological factors can impact BIM adoption. The HOT fit model can help CPOs evaluate their general HOT fit status, redesign optimal HOT configuration, diagnose the problems when the HOT fit is not ideal, and make strategic directions to better harvest the benefits of BIM. Limitations and future research directions are also identified.

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1 Introduction

The architecture, engineering, construction, and facility management (AEC/FM) sector has long been criticized for being slow-moving in embracing innovation and digitalization technologies (Davies & Harty, 2013). A widely referred example is the sluggish and immature implementation of Building Information Modeling (BIM) (Dakhil et al., 2019), which is expected as a game-changing digital technology to enable construction's digital transformation. Organizations are suffering from various problems from technical, managerial, personnel, procedural, and institutional aspects to fully harness the promised power of BIM. It is further observed that different construction organizations have different experiences in harnessing the benefits of BIM. Even some similar organizations may still have divergent BIM experiences among different projects.

The lack of a standard solution for BIM adoption is partly rooted in the characteristics of the construction industry. As a highly project-based industry, it is featured with temporality (Lundin & Söderholm, 1995), dynamism (Söderlund & Sydow, 2019), complexity (Hobday, 2000), uncertainty (Sanderson, 2012), specialization (Söderlund, 2011), fragmentation (Fellows & Liu, 2012; Söderlund, 2011), and conservativeness (Engwall, 2003). Apart from them, organization-level issues, such as availability of qualified staff and effective leadership (Ozorhon & Karahan, 2017) and coordination among works, professionals, and groups (Antwi-Afari et al., 2018), also challenge the successful BIM adoption.

As put by Papadonikolaki et al. (2019) and He et al. (2017), although the technical maturity of BIM is advancing, the managerial maturity of BIM is waiting for attention and developments. Most organizations are just chasing the fashion without assessing their readiness and fitness for successful BIM adoption and adaptation. Some even fail to be aware that new technology requires humans to be accustomed to it and organizations to adapt their structures and processes (Bhatt, 2001). The organizational unreadiness and unfitness for BIM press severe hurdles for harvesting the technology's potential benefits (Antwi-Afari et al., 2018; Ozorhon & Karahan, 2017). Nevertheless, few researchers attended to this problem or proposed acceptable explanations and solutions. Specifically, as pointed out by Hasan et al. (2021), extant studies have neglected the interrelations between human, organization, and technology.

The authors aim at investigating how human, organization, and technology factors influence BIM adoption in construction project organizations (CPOs). Since the human, organization, and technology factors are highly impactful for technology adoption in CPOs (Hasan et al., 2021) and they should be rigorously evaluated in a joint manner (Yusof et al., 2008), this paper propose that the fit among the three dimensions (i.e., Human-Organization-Technology fit or HOT fit) as a new perspective to investigate the BIM adoption (Xu and Lu, 2020). Specifically, it will: (1) develop a holistic HOT fit model to collectively consider human, organization, and technology in BIM adoption; (2) investigate how related factors impact the HOT fit of BIM projects; and (3) provide strategic suggestions for CPOs to better harness the power of BIM. Using empirical data collected from 14 BIM projects, it will adopt a mixed method that integrating social network analysis (SNA), comparative cases study, and regression analysis. SNA, a widely adopted tool to measure interactions among team members in AEC/FM industry, provides metrics for measuring interaction patterns (Eray et al., 2021). SNA metrics will be used as the data source to calculate HOT fit level in this study. Comparative cases study will be applied to measure the HOT fit by comparing professional's network metrics in BIM and Non-BIM projects which form a comparative reference system of BIM projects. Regression analysis will be finally utilized to uncover the impacts of different factors on HOT fit. The rest of the paper is organized as follows: Section 2 will summarize existing research on BIM adoption while Section 3 will introduce the proposed HOT fit model; research methods will be explained in Section 4 followed by data analysis and findings in Section 5; finally, discussion and conclusions will be made in Sections 6 and 7, respectively.

2 Research on BIM adoption

BIM acts as a reliable shared knowledge resource for informed decisions during the lifecycle of a facility (Sacks et al., 2018). Attracted by its prospects, governments of all levels take BIM as an empowering strategy and attempt to make it compulsory in public projects; companies with relevant business are competing to launch BIM lest they will be left behind by competitors (Lu et al., 2020). With the development of BIM in the last thirty years, it is becoming a full integration and collaboration hub for the lifecycle management of buildings and infrastructures, which can involve the inclusion of time/schedule management, budget calculation/quantity take-off, and lifecycle facility management dimensions (Ribeirinho et al., 2020). Other tasks BIM can enable or support include feasibility study, environmental analysis, clash detection, shop drawing creation, constructability visualization, geospatial coordination for atypical components, schedule management for installation, and as-built model creation for facility management (Lee et al., 2015).

The emerging BIM adoption has attracted plethora of studies which generally depart at two levels: the project level and the organizational level. The former mainly investigates the changing relationships, especially the multi-disciplinary collaboration relationship, among project stakeholders before and after BIM adoption. While at the organizational level, the key research topics are: (1) the process of BIM adoption, (2) the drivers and factors that affect BIM adoption, and (3) relationships between organization characteristics, such as size, structure, types, and organizational BIM adoption performance. These studies discussed the benefits and the hurdles of BIM adoption, as summarized in Table 1 from general, human, organization and organizing, and technology aspects. Although the benefits mainly go for organization and technology aspects, majority of hurdles comes from human and general management aspects.

The distribution of benefits and hurdles indicate that human, which has received scant attention in previous research, is one of the bottlenecks of further BIM adoption. The industry concentrates on using BIM to create, store, share, visualize, and manage information but pays scant attention to the using and managing of these functions (Liu et al., 2017). Humans should draw equal attentions as organization and technology. Otherwise, it is difficult to establish overall BIM adoption eff ectiveness, manageability of real-time BIM outcomes, and high adoption rates (Ahmed & Kassem, 2018). Further probes are required to study the effects of human factors on BIM adoption and their concurrent effects with organization and technology.

3 The HOT Fit Model for BIM Adoption in CPOs

As thoroughly reported in prior work (Xu, 2021; Xu and Lu, 2021), the theoretical HOT fit model was developed based on theories related to technology adoption. The model holistically incorporates human, organization, and technology dimensions, together with their characteristics. The three dimensions mutually interact with and influence each other through their bi-party relationships, i.e., the HO fit, HT fit, and OT fit, and finally impact the overall HOT fit. Fit is defined here as the congruence or matching between different elements (Venkatraman, 1989; Kristof, 1996). Fit is a status that can be perceived or evaluated from different aspects. This paper will not go deep to discuss its theoretical explanations and dimensions, interested readers may refer to the extant literature on fit. In this paper, HO fit is the congruence between human and organization, HT fit is the congruence between human and technology, OT fit is the congruence between organization and technology, while HOT fit technology is the congruence between human, organization, and technology. The HO fit, HT fit, and OT fit values will be directly measured to assess how two of the three dimensions match with each other. The will then be used to calculate the overall HOT fit. The theoretical HOT fit model is generally developed for technology adoption in organizations. It aims to offer a holistic view of the indispensable aspects of technology adoption instead of investigating them in a fragmented manner as previous studies usually did. This paper goes on to contextualize it to BIM’s adoption in CPOs and further operationalize it for the quantitative analysis of influencing factors on the HOT fit. Such analysis will uncover some underlying mechanisms of HOT fit and provide empirical evidence for CPOs to strategize their technology adoption plan.

The 'human' discussed in this study is the professionals in CPOs. They have specialized skills and knowledge, they need to communicate, coordinate, and collaborate with other professionals, and they are classified by specialized area and position ranking. Every professional in a CPO is highly dependent on other professionals because all the tasks they executed are highly interrelated. Even more, they need to work with others they do not know at all because most CPOs are temporary organizations put together by people working for different companies or subdivisions. Thus, the professionals in CPOs have to face much more uncertainties and contingencies, making the adoption of technology even harder. In CPOs, the professionals can be further divided into two types: professional engineers with specialized expertise and technical officers who obtain both professional knowledge and management skills. In a CPO, these characteristics can be represented by professional type and professional rank. They are both directly affected by technologies.

CPOs are perceived as temporary project-based organizations (PBOs) to fulfill a predefined construction project by an interdependently organized group of humans with specialized skills (Ajmal & Koskinen, 2008; Miterev et al., 2017). The success of a CPO requires various specialized professionals to partner, collaborate, coordinate, and communicate efficiently towards the same goal. The CPO contextualized in this research is a project management office transferred from the parent organization. Various internal and external organization characteristics will impact its fit. Organization size and structure are the fundamental characteristics that influence the different fits in similar CPOs under the same overarching organization while the external characteristics and overall IT strategy of different CPOs are more or less the same.

As stated, BIM is the focal technology of this research. Since every construction project is unique, even the same quality of BIM with the same hardware, software, and skills are applied in the same organization, BIM LOD and application scenarios are the characteristics that distinguish one BIM technology from another. Accordingly, the proposed HOT fit model for BIM adoption in CPOs is as displayed in Figure 1. The rest of this paper will examine the effects of different factors on the HOT fit using SNA and comparative case study.

4 Research methods

4.1 Comparative case study

The overarching research methodology of this work is case study. Case study is "an empirical inquiry that investigates a contemporary phenomenon (the 'case') in-depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident" (Yin, 2014, p. 16). It provides investigators with a holistic and realistic perspective to comprehend complex social phenomena (Yin, 2014). The case study method is prestigious, especially in a comprehensive and thorough investigation of particular questions (Flyvbjerg, 2006). Two or more cases can be investigated for comparisons in case study research. The comparative method is widely used to establish empirical propositions of relationships among various factors (Lijphart, 1971). Generally, a comparative case study is an efficient, reliable, and robust method used to examine the impacts of a particular intervention by comparing two or more literally replicated cases that have one and only contrasting condition (Yin, 2014). An essential prerequisite of a comparative case study is to ensure the 'replicability' or 'equivalence' (Esser & Vliegenthart, 2017).

The comparative case study can allow us to investigate questions of "how" some factors influence the outcome with more generalizable findings through cross-case comparisons (Eisenhardt, 1989; Oliveira & Lumineau, 2017; Van de Ven & Poole, 2005). It has been employed by much research. For example, Badi & Diamantidou (2017) utilized a comparative case study of two construction projects, one used BIM and the other not, to understand BIM's impact on the roles and relationship of project participants in inter-organizational communication. Inspired by this research stream, this study employs two types of cases to calculate the HOT fit level of BIM projects by comparing its discrepancy with Non-BIM projects. The two types of cases have similar settings, except for the use or non-use of BIM.

4.2 Social network analysis

Construction project organizations (CPOs), a special type of temporary PBO (Hobday, 2000), can also be viewed as social networks (Burke & Morley, 2016; Chinowsky et al., 2010). By conceptualizing

CPOs as social networks, it helps with the understanding of the relationships in projects, as well as provides a theoretical foundation to employ SNA as a core method. There is numerous research studying CPOs using SNA. SNA can help examine the position of actors, the interacting relationships between actors, as well as their structures and attributes within CPOs (Chinowsky & Taylor, 2012; Lu et al., 2020; Pryke, 2004, 2012; Steen et al., 2018; Wasserman & Faust, 1994). Recent studies have explored the application of social network perspectives to the study of BIM in CPOs (Badi & Diamantidou, 2017; Lu et al., 2020; Merschbrock et al., 2018).

With nearly eighty years of development, SNA is developed into a comprehensive method to analyze structures and relationships. It provides various network metrics to uncover the underlying characteristics of the network and visualization options to illustrate the properties of the networks (Pryke et al., 2017). These metrics quantify the node standing, relationships between nodes, or overall network features. For example, average path length (*APL*), betweenness centrality (*BC*), and closeness centrality (*CC*) are widely used metrics. *APL* is also a metric to gauge the distance between nodes as it refers to the average extent of convenience for the nodes in an organization to reach each other. The *BC* indicates the capability to bridge groups of otherwise disconnected nodes (Bueno, 2015). One actor's *BC* is calculated as the count of shortest paths between others going through the node. Therefore, a node with larger *BC* will be more powerful and influential in organizational coordination (Hossain, 2009; Pryke et al., 2018) and is usually named as a "knowledge broker" (Wen & Qiang, 2016). The *CC* weighs both direct and indirect edges of a node to other nodes in the network. Therefore, measuring the proximity of a node to both its direct neighbors and all other nodes indicates the degree a node lies at the shortest distance to other nodes. Theoretically, the larger the *CC*, the closer is one node connected to other nodes in the network, and also the faster and the more independent he/she is in reaching others (Wang et al., 2018).

This study will follow this direction of analysis and take advantage of these network metrics, as well as the graphic presentations, to measure and visualize the HOT fit level of CPOs. Explicitly, *CC* will be applied to measure the BIM's impact on human interaction efficiency; *APL* will be employed to investigate how BIM influences overall organizational information delivery efficiency, while *BC* will be adopted to individual's significance of information control in the CPO.

The interaction matrixes will then be imported into network analysis software to generate social networks and calculate their metrics. In the social networks, professionals and officers of the CPO are the nodes and their interaction in the projects are the edges. Among the various software packages, *Gephi*, is selected to visualize and analyze the interaction networks among the members in CPOs. *Gephi* is a free and open-source network exploration and visualization software. It is more user-friendly because it requires no deep knowledge of graph theory and no coding or programming (Jacomy et al., 2014). It is also stronger in visualization (Faysal & Arifuzzaman, 2018). It supports the customization of color, size, labels, and layout for better network visualization and provides various node and network metrics for further analyses (Apostolato, 2013). Although it does not support some functions, such as cohesion and change detection, it can meet the needs of this study. *Gephi* 0.9.2 version is used in this paper.

4.3 Operationalizing the HOT fit in CPOs' BIM adoption

4.3.1 Human-technology fit

The contextualized interaction between engineers, technical officers, and BIM is reflected in the professional-BIM fit. If professionals' abilities can match BIM requirements, professionals can be better connected and bonded (Huang et al. 2020), boost information communication, and enhance collaboration. Such evidence can be mirrored in the professional interaction networks by closer relationships (represented by larger *CC*) between different nodes. The *CC* measures the ability to approach others in a short time, which can reflect whether BIM enables quicker communication among professionals. By comparing the professionals' *CCs* in the networks of BIM project and a comparable Non-BIM project, the overall $HT\ fit$ index can be calculated using Formula 1:

$$HT\ fit = \frac{\sum_1^n (HT\ fit)_i}{n} = \frac{\sum_1^n (\frac{H_{T_i} - H_{nT_i}}{H_{nT_i}})}{n} \quad (1)$$

The $HT\ fit$ is the average of all professionals in the organization. $(HT\ fit)_i$ is the individual HT fit of Professional *i*. H_{T_i} and H_{nT_i} are the *CCs* of professional *i* in the BIM project and the compared Non-BIM project, respectively. *n* is the total number of professionals in the CPO. If the professional and BIM are in a good fit, his/her *CC* in the BIM project network will be much larger than that in the similar Non-BIM projects. Thus, the $HT\ fit$ of that professional will be larger than *0*. Overall, the larger the $HT\ fit$, the better fit the CPO professionals with the BIM technology.

4.3.2 Organization-technology fit

Organization and technology characteristics interplay with each other and influence HOT fit through the OT fit. OT fit means the CPO is ready for the BIM adoption and the BIM adoption suits the CPO. The $OT\ fit$ index is measured by comparing the network *APL* of a BIM project and its comparable Non-BIM project, see Formula 2:

$$OT\ fit = \frac{O_{nT} - O_T}{O_{nT}} \qquad (2)$$

Where O_T is the *APL* of the BIM project network, while O_{nT} is the APL of the counterpart Non-BIM project network. The *APL* is selected as the network metric to measure the OT fit because it denotes the end-to-end delay for information delivery. If CPO and BIM are in a good fit, information can be smoothly delivered in the organization and the *APL* of the BIM project will be much smaller than the Non-BIM projects, then the OT fit index will be more approximate to *1*. That is, the larger the *OT fit*, the better the CPO and BIM fit with each other.

4.3.3 Human-organization fit

The fit between humans and the organization is an unneglectable environment and a significant prerequisite for technology adoption. Without HO fit, technology adoption will be hindered by human or organization issues such as insufficient professionals, unreasonable organization structure, or low incentives to promote the technology. The $HO\ fit$ index will be measured by comparing professionals' *BCs* in the social network of a BIM project and that of a similar Non-BIM project. Here, the *BC* is chosen to measure the $HO\ fit$ because it measures the ability to control knowledge sharing paths. It reflects the actual power and influence of a node in the social network, which is the real-life interaction between professionals concerning their works. As BIM is supposed to change the knowledge sharing patterns among professionals in CPOs, so the *BC* can reflect the fit between professionals and organizations. Thus, the $HO\ fit$ is operationalized through objective comparison among comparative BIM and Non-BIM projects instead of using survey methods to estimate the subjective HO fit. Therefore, the $HO\ fit$ is calculated using Formula 3:

$$HO\ fit = \frac{\sum_1^n (HO\ fit)_i}{n} = \frac{\sum_1^n \left(\frac{H_{O_i} - H_{nO_i}}{H_{nO_i}}\right)}{n} \qquad (3)$$

$(HO\ fit)_i$ is the individual $HT\ fit$ index of Professional i. The $HO\ fit$ is the average of all professionals in the organization. H_{O_i} and H_{nO_i} are the *BCs* of the professional *i* in the BIM project and the Non-BIM project, respectively. If the professional and organization are in a good fit in the BIM project, his/her *BC* will be much larger than that in the similar Non-BIM projects, his/her individual $HT\ fit$ will be larger. Overall, the larger the $HT\ fit$, the better the professionals are well fitted with their CPO.

4.3.4 Human-Organization-Technology Fit

The HOT fit contextualized in this study is the triangulated balance among the engineering and management professionals, the CPO, and BIM. In metaphor, the three constructs are the three vertexes of the HOT triangle, while the three bi-party fits are the three edges. The overall $HOT\ fit$ level is dependent on the three bi-party fit indexes. Their optimal states can make the triangle a stable one. For different fits, their optimal states are different. According to Formulas (1) to (3), for HT fit and HO fit, they reach an optimal state when their fit index is larger than *0* and as large as possible; while for OT fit, its optimal state is the index being larger than *0* and infinitely close to *1*. Therefore, there is no best state but just better ones. An optimal state is that the three fit indexes are all larger than *0*. If any of $HT\ fit$, $OT\ fit$, and $HO\ fit$ is smaller than the critical value *0*, the triangle will need to adjust for another balance or even collapse. To address that any of the three bi-party fit indexes are of equal, independent, and direct significance to HOT fit, we will use multiply operator between them to calculate the $HOT\ fit$ index. It should be stated that this does not mean the three fits are mathematically independent because they may have some influence on each other. Readers are suggested to focus on the semantic meaning of the relationship instead of sticking with the mathematic one. Therefore, the overall $HOT\ fit$ index is measured by multiplying the three bi-party fit indexes, see Formula 4.

$$HOT\ fit = HT\ fit\ \times OT\ fit\ \times HO\ fit$$

$$= \frac{(O_{nT} - O_T)\sum_1^n(\frac{H_{T_i} - H_{nT_i}}{H_{nT_i}})\sum_1^n(\frac{H_{O_i} - H_{nO_i}}{H_{nO_i}})}{n^2 O_{nT}} \quad (4)$$

It should be supplemented that the $HOT\ fit$ index will be negative if there is any negative value in the $HT\ fit$, $OT\ fit$, and $HO\ fit$ indexes. That is, if there are two negative values, the $HOT\ fit$ index will be negative all the same although the mathematical calculation of Formula (4) will be positive. As the ideal state is that the $HT\ fit$, $OT\ fit$, and $HO\ fit$ indexes are all positive and as larger as possible, then, the larger the $HOT\ fit$ index, the better fit is the organization and its members with BIM adoption.

5 Data Analysis and Findings

5.1 Case selection and data description

The data of 17 BIM projects and 10 non-BIM projects was provided by Organization A, a large public development organization in Hong Kong. All the projects are public residential housing buildings with some ancillary facilities. Following the criteria that the project data should have no missing record and the projects should form comparable pairs, 14 BIM projects and 6 Non-BIM projects are selected for this study. Although no two projects are the same, they have comparability between each other. Moreover, it is better to calculate the HOT fit index by referencing projects that are more similar than comparing among projects that are very different from each other from contract sum, project duration, and construction scope. A referencing system is a better choice. The referencing relationships are assigned according to the contract sum, the building types, and the volume to be built to ensure their reasonability and comparability for the evaluation of HOT fit indexes. Specifically, the referencing relationship is shown in Table 2.

Organization A well records the works done by the staff of the project management office, a CPO, in residential housing development projects and therefore leaves behind a rigorous timesheet of the projects. A CPO houses forty to sixty professionals, depending on the project requirements. Since every project are governed by the same Organization A, the organization structure of the CPOs is more or less the same. The timesheet keeps a record of almost every non-trivial project activity with individual actors' ranks and time to conduct these activities alongside the construction processes. The dataset recorded the project IDs, time (by month), role ranks, task codes, normal hours, and cost, as well as overtime hours a task consumes, see Appendix 1. It keeps good track of the work-oriented social relationships amongst the project management team members throughout the construction process. They contribute a very good data source for SNA.

The roles are the CPO professionals from different divisions, such as architecture (A), quantity surveying (QS), civil engineering (CE), structure engineering (SE), geotechnical engineering (GE), and building service engineering (BSE). Different professionals interact (i.e., do things with each other) in the project, forming an interaction matrix generated from the timesheet that records the work-oriented social relationships. The interaction strength is operationalized by calculating the times different professionals working collaboratively for a same task during the same month, such data is recorded in the timesheet provided by Organization A. For different projects, the number of professionals involved varies, see Table 3. Inputting an interaction matrix into the SNA software *Gephi*, the social networks of the corresponding CPO can be created, illustrated in Figure 2. Then, the network metrics including *APL*, *BC*, and *CC* can be extracted for later analysis.

5.2 Data analysis and results

SNA was conducted in all the BIM and non-BIM projects to extract the required network metrics. Using a comparative case study, the HT fit, OT fit, HO fit, and HOT fit can be calculated using Formulas 1-

4, respectively. The results of the four fit indexes and the project-level characteristics are displayed in Table 4. Averagely, HT fit index, OT fit index, and the overall HOT fit index are negative. The standard deviations (SD) of all dimensions are relatively small, indicating that there are trivial differences among the 14 BIM project cases. To scratch the relationships between different quantifiable characteristics and the fit indexes, regression analyses are conducted to explore the correlations between the fit indexed and the quantifiable organization characteristics (organization size and structure), technology characteristics (BIM LOD). Especially, organization size is represented by project contract sum while organization structure by the hierarchy steepness which is the standard deviation of all hierarchy levels (Bunderson et al., 2016; Cantimur et al., 2016). Multiple regression of combined characteristics is also performed to examine the impacts of joint factors. The impact analyses of unquantifiable BIM scenarios and the human-level factor (professional type and rank) will not be reported in this paper due to the length limitation.

The correlation coefficients (Multiple R) of the regression analysis results are displayed in Table 4. In many social science studies, a significance level less than 0.05 is a rule, it represents that the model is less than 5% wrong. However, this study also admits those results with a significance level less than 0.1, which means the results represent 90% of the truth, considering the limited number of cases and their variations. Readers should bear in mind that this regression analysis is based on the results of 14 BIM projects and it may limit the reliability of the results. The ideal ratio of sample size and variables should be in the range of 3 to 6 or a minimum of 5 (MacCallum et al., 1999). Therefore, the 14 inputs just meet the sample size requirements with three variables for factor analysis.

5.2.1 HOT fit

It is found that only 2 projects (B2 and B3) have positive HOT fit indexes, i.e., only the 2 out of 14 BIM projects achieve a better HOT fit than their Non-BIM counterparts. Projects B1, B6, B10, and B13 have HOT fit indexes just slightly smaller than 0, barely any significant difference with their Non-BIM counterparts. However, the other seven projects, i.e., B4, B5, B7, B8, B9, B11, B12, and B14, perform worse than their Non-BIM equivalents.

The regression analyses disclose some high correlations. The HOT fit index has a significantly negative relation with project size with a correlation coefficient of 0.7812: $HOT\,fit = -7.1021 \times 10^{-10} \times PS + 0.5658$ (p=0.00097). The higher the project contract sum, the poorer HOT fit performance. HOT fit index is not found to be significantly correlated to hierarchy steepness or BIM LOD. For two-factor combined regression analyses, the combination of project size and hierarchy steepness, as well as project size and BIM LOD, are found to be highly relevant to the HOT fit index, with $HOT\,fit = 0.1841 \times HS - 6.8375 \times 10^{-10} \times PS - 1.6459$ (p=0.0054) and $HOT\,fit = -6.8667 \times 10^{-10} \times PS - 0.0065 \times BL + 2.6177$ (p=0.0015). When using the three characteristics together, there is a highly correlative relationship (*correlation coefficient*=0.8337): $HOT\,fit = 0.0215 \times HS - 6.8365 \times 10^{-10} \times PS - 0.0065 \times BL + 2.3541$($p$=0.0062). This formula serves as a reliable model to measure the HOT fit index. It implies that the project size and BIM LOD are negatively related to the HOT fit index meanwhile hierarchy steepness is positively related to it. That is, the flatter the hierarchy, the larger the project size, and the higher the BIM LOD, the more difficult it is to achieve a high HOT fit.

5.2.2 HT fit

Compared to the overall HOT fit, there are more projects performing better in HT fit perspective. However, still, more projects are performing worse (8) than performing better (6) compared to their Non-BIM counterparts in HT fit. The absolute values of the HT fit index are very small (less than 0.1), showing the slight discrepancy between the BIM project and Non-BIM project, either negative or positive. The regression results show that the HT fit index is moderately correlated with both of the organizational characteristics. Specifically, HT fit index is positively related to hierarchy steepness: $HT\,fit\,index = 0.0759 \times HS - 0.9234$ (p=0.022), and negatively related to project size: $HT\,fit = -1.9960 \times 10^{-11} \times PS + 0.0056$ (p=0.033). HT fit index is not found to be significantly related to BIM LOD.

When combining the characteristics, stronger correlations emerge. Especially, hierarchy steepness and project size, project size and BIM LOD, hierarchy steepness and BIM LOD are moderately correlated with HT fit index: $HT\,fit = 0.0530 \times HS - 1.2342 \times 10^{-11} \times PS - 0.6311$ (p=0.035), $HT\,fit = -1.8835 \times 10^{-11} \times PS - 0.00031 \times BL + 0.1036$ (p=0.035), and $HT\,fit = 0.0691 \times HS - 0.00027 \times BL - 0.7563$ (p=0.033). Hierarchy steepness, project size, and BIM LOD together are highly correlated with HT fit index: $HT\,fit = 0.0462 \times HS - 1.2338 \times 10^{-11} \times PS - 0.00027 \times BL - 0.4641$ (p=0.038). The results revealed that: (1) steeper hierarchy and smaller project size are related to better HT fit; (2) smaller project size and lower BIM adoption level is associated with higher HT fit index; (3) steeper hierarchy and lower BIM adoption level are connected to better HT fit; and (4) steeper hierarchy, smaller project, and lower BIM adoption level are linked to higher HT fit index.

5.2.3 OT fit

Same as the overall HOT fit index, only 2 projects, B2 and B3, have positive OT fit indexes. All the absolute values of the OT fit index are very small, less than 0.2, denoting that the balance between organization and technology is not considerably impacted by the adoption of BIM. OT fit is found to have a weak positive relationship with hierarchy steepness, a moderate negative correlation with project size, and only a weakly negative relationship with BIM LOD: $OT\,fit = 0.0733 \times HS - 0.9213$ (p=0.099), $OT\,fit = -2.2934 \times 10^{-11} \times PS - 0.0166$ (p=0.059), $OT\,fit = -0.00053 \times BL + 0.1100$ (p=0.077). Thus, the steeper the hierarchy, the better is the OT fit; the larger the projects or the higher the BIM LOD, the harder to research high OT fit.

When integrating different characteristics together, stronger relationships can be detected. While the joint of hierarchy steepness and project size has no significant relationship with the OT fit, the combination of hierarchy steepness and BIM LOD and the joint of project size and BIM LOD have a moderate correlation with it: $OT\,fit = 0.0618 \times HS - 0.00046 \times BL - 0.6383$ (p=0.071), and $OT\,fit = -2.1179 \times 10^{-11} \times PS - 0.00049 \times BL + 0.1363$ (p=0.033). When combining the three characteristics together, an even stronger moderate correlation is found: $OT\ fit = 0.0305 \times HS - 1.6891 \times 10^{-11} \times PS - 0.00046 \times BL - 0.2384$ (p=0.072).

5.2.4 HO fit

It is noticeable that the ranking of HO fit index is quite divergent. In other rankings, B2 and B3 are among the highest-ranking and B4, B5, and B12 are among the lowest ranking. However, in this HO fit index ranking, B10 and B1 are the highest-ranked, while B13 and B14 are the lowest-ranked. This difference also indicates that although HO fit is positive and large, its impact on the overall HOT fit index is not that significant because a well-fitted human, organization, and technology relationship requires every aspect to be well fitted. Although the high value of the HO fit indexes is partly due to the calculation method, their positive values indicate the adoption of BIM improves the congruence between professionals and the CPO to a significant extent. Meanwhile, the differences of the HO fit indexes between different BIM projects are actually very substantial, with the largest one is 434.46 while the smallest one is 71.35, showing that although positive, BIM's benefit for the HO fit ranges among projects.

Hierarchy steepness is moderately correlated with the HO fit: $HO\ fit = 153.4195 \times HS - 1582.94$ (p=0.047). When combining two factors, hierarchy steepness and project size, hierarchy steepness and BIM LOD are moderately related to HO fit: $HO\ fit = 214.1594 \times HS + 3.2778 \times 10^{-8} \times PS - 2359.2$ (p=0.052), $HO\ fit = 135.4044 \times HS - 0.7199 \times BL - 1140.2$ (p=0.049). Finally, the combination of the three characteristics is highly correlated with HO fit with a correlation coefficient of 0.7406: $HO\ fit = 196.1591 \times HS + 3.2789 \times 10^{-8} \times PS - 0.7201 \times BL - 1916.6$ (p=0.040).

5.3 Result reflection

This section will summarize the data analysis and results in Section 5.2 and make some reflections on them.

5.3.1 The impact of organization factor on HOT fit

In this study, the steeper hierarchy was testified to benefit the HOT fit in CPOs which is typified with complex tasks. The finding is evidenced by the significant positive correlation between *hierarchy steepness* (*HS*) and HT fit, OT fit, and HO fit, as well as the significant correlation between the HOT fit and combined hierarchy steepness and project size. It is speculated that a steeper hierarchy indicates less redundancy and therefore can reduce conflict and facilitate coordination, which is an outstanding selling point of BIM. However, it is unsure whether such benefits are compromised by their drawbacks, such as "reducing member motivation and stifling innovation" (Bunderson et al., 2016, p. 1265). Another possible rationale behind the functional benefits of a steeper hierarchy can be the lowered necessity to incorporate as many professionals with different detailed levels of knowledge in BIM-adopted CPOs as in conventional CPOs. Accordingly, CPOs can apply steeper hierarchical structures when BIM is adopted. By saying so, it means laying off some professional roles that become redundant in BIM-adopted CPOs. CPOs can further steepen the organization's hierarchical system by raising the authorities and salaries of the key roles to stimulate the competitions and innovations.

5.3.2 The impact of technology factor on HOT fit

Twelve out of fourteen projects with negative HOT fit indicates that the studied CPOs are not very ready with BIM adoption, especially with high LOD BIM. The results are even aggravated when the project size increases, as validated by the significant negative correlation between project size and HOT fit. The findings imply that organizations should not try high-level BIM or complex applications when they are not technologically ready. A workable strategy is collecting experiences and meanwhile training humans starting from lower LOD BIM in smaller projects. LOD200 that supports simple 3D visualization is a good point of departure to let professionals get accustomed to the functions and operations of the BIM software. After the training from several such projects, CPO can apply similar LOD BIM in larger projects. It is easy to do so, although there are more to consider in large projects. Simultaneously, CPOs can also try higher level BIM in small projects. By adding more details to the models, professionals will be able to advance their knowledge, skills, abilities, and other characteristics

(KSAOs) about BIM and improve the intra-organizational cooperation and collaboration among team members. Finally, when the professionals are well trained, and CPOs are well adjusted to the BIM adoption, higher BIM LODs can be applied to larger projects.

BIM technology could be adapted for HOT fit. It is found the HOT fit level is sensitive to BIM application scenarios and project types, as the HOT fit varies with BIM LOD and application scenarios. Professionals and CPOs have to explore how to apply BIM to different scenarios in different types of projects. The technology vendors can do more by providing solutions for different project types and application scenarios. With such solutions, the thresholds for professionals and CPOs to adopt the technology will be lowered. The technology diffusion and adoption will be more efficient. Professionals and CPOs can grasp the technology quicker and achieve a higher HOT fit level in an easier way.

5.3.3 The impact of human factor on HOT fit

The professional type and rank have impacts on the HT fit and HO fit. Although the results are not reported in this paper due to the length limitation, we could report some general findings here: while BIM enhanced the HO fit for all professional ranks, averagely, higher-ranked professionals have less HT fit than their lower-ranked subordinates; engineers and technical officers have higher HO fit than the senior engineers and superiors and their assistants. Senior ones may feel stressed in their organizations in the context of technology adoption; the impact of professional type on HT fit is scenario-sensitive, which further implies that to better harness the power of BIM, a holistic HOT fit perspective is desired. The HOT fit model can also help engineers and technical officers better adapt themselves for better HT fit, HO fit, and HOT fit. As indicated by the cases, the architects, landscape architects, civil engineers, structural engineers, building service engineers, quantity surveyors, technical officers of civil engineering, and technical officers of building services should improve their HT fit. For HO fit, engineers and technical officers performed better than the senior and assistant ones. Therefore, senior engineers and senior technical officers should learn from the junior ones, try to learn more about the technology, and enhance both their HT fit and HO fit. Engineers and technical officers should enhance their technological abilities to increase their HT fit. Assistant professionals should quickly adjust to the organization by work with their supervisors and contribute more efforts in technology adoption for the organization to improve their HO fit.

6 Discussion

This research proposed an answer to the research question about how construction project organizations (CPOs) can strategize their Building Information Modelling (BIM) adoption. The answer is that CPOs should reach a good Human-Organization-Technology (HOT) fit based on their organization structure, BIM adoption objectives, and the professionals' status. Human, organization, and technology are indispensable and interdependent in BIM adoption processes. However, different configurations of the three can lead to different HOT fit levels. Take the fourteen BIM projects as examples, although they all adopt BIM and are all CPOs from the same client's side, their HOT fit levels differ. Firstly, their organizational configurations as characterized by hierarchy steepness and project size differ. Secondly, their technology adoption features vary from one to another, as evidenced by different BIM LODs and application scenarios. Thirdly, professionals are distinctive humans with different ranks and KSAOs. Thus, their interactions lead to varied overall HOT fit levels and consequentially result in different performances of the same technology in similar organizations.

This research makes four unique contributions of knowledge and practices to management in engineering domain. First and foremost, it sheds light on 'human', which is largely forgotten in engineering management research. This research brings human back to the stage and views human as a central and focal point. Different from existing BIM research that takes frontline workers on construction site as their subject of study, for example, Mäki and Kerosuo (2015) investigated the BIM use of site managers, Bråthen and Moum (2016) studied BIM adoption by construction workers, this research focuses on professional engineers and officers in the management offices. This research addresses professionals as the kernel of organizational technology adoption process (Miettinen and Paavola, 2014) and their professional KSAOs are the engine to promote technologies like BIM in CPOs.

The second unique and genuine contribution is the development of the HOT fit concept and model. Existing BIM related studied pay majority of their attention to technological and organizational spheres. They investigated BIM's technical applications in construction activities such as scaffolding planning (Kim et al., 2018) and quantity take-off (Kim et al., 2019), BIM's impact on organizational coordination (Jang et al., 2019) and collaboration (Li et al., 2021), project management (Ma et al., 2018), stakeholder management (Gaur and Tawalare, 2022), and project performance (Tang et al., 2019), as well as broad factors influencing BIM implementation (e.g., Liao et al., 2021). The HOT fit model is the first to attach equal significance to human factors, organizational factors, technological factors, and their inter-relationships to tackle BIM adoption issues. With the comprehensive HOT fit model as a theoretical lens, researchers can broaden their theoretical visions, advance theoretical perspectives, and develop theoretical solutions for the problems associated with organizational technology adoption. It can be widely applied from three aspects: (1) CPOs can use the conceptual HOT fit model to qualitatively evaluate the characteristic status of human, organization, and technology to check which factor might be weak or go wrong. It can also provide directions on how to enhance the bottlenecks to foster a better HOT fit. (2) At the design stage of a CPO, the HOT fit model can be applied to compare different design options quantitatively. For example, given organizational structure and project size, it can compare which LOD of BIM is optimal for the project. Alternatively, on another aspect, when the BIM LOD is decided, how to organize the CPO to match the requirements of the project. (3) During project implementation, if there is something going wrong, the HOT fit model can help diagnose the problems. By calculating the indexes of the bi-party fits, it will be very clear to check which aspect is pulling back the HOT fit and advise further amendments.

The third unique contribution is the new methodology to measure the HOT fit level quantitatively. Previous BIM implementation research collect function diffusion or critical factors using questionnaire survey (Gholizadeh et al., 2017; Liao and Teo, 2018), use social network analysis method to investigate inter-organizational project-based collaboration networks (Cao et al., 2018) or sociotechnical components (Merschbrock et al., 2018). Researchers are frequently hampered by the difficulties of collecting and analyzing project-level data, especially the micro-level data of human behaviors. The truth is the available big data is buried without discovery eyes and exploratory insights. This research made full use of the data unintentionally left behind. These passive and objective records kept good track of the activities of all the professional engineers and officers when they are delivering projects. By converting the co-occurrence matrixes of the professional into social networks, the actual organizational structure and relationships can be delineated. The social network metrics such as betweenness centrality, closeness centrality, and average path length are used to describe the organization's characteristics or the standing of a human in the organization. Taking advantage of the metrics can help with analyzing the fitness condition of the organizations and humans. When furtherly comparing projects adopting a technology and equivalent projects without the technology, the HOT fit level can be quantitatively measured.

The fourth unique contribution is the significant research finding of steeper hierarchy structure being beneficial for HOT fit, which is unexpected and contradicts to previous arguments in contingency theory and organization science. It implies that, BIM, as a complicated technology, calls for more organized instead of looser structure. It challenges the contingency theory to consider the function of technology rather than just the complexity of the technology. Because some technologies can enable better information communication and availability and thus alleviate the negative effects of steep hierarchy on information communication. The finding is also contradictory with the arguments in organization science that (Anderson & Brown, 2010) steeper hierarchy has a negative impact on technology adoption. One possible explanation is that the negative effects of steeper hierarchy can be counteracted by the positive effects of information technology so that its hindrance on information flow is not obvious.

Finally, we would like to acknowledge that the technology adoption issues have no simple and perfect solution, especially for complex technology like BIM and its adoption in temporary and fragment organizations like CPOs. Aimed to solve a big problem with constrained time and data, this research is bound to limitations including: (a) limitation of case numbers; (b) no comparable analysis among different AEC/FM stakeholders; (c) no longitudinal analysis for the HOT fitting process; and (d) simple research context. Future research could add more case numbers and analyze from different perspectives to enrich the research findings.

7 Conclusions

The sluggish and immature adoption of Building Information Modelling (BIM) technology in the architecture, engineering, and construction (AEC) sector has drawn much attention in the management in engineering community. Existing research has studied the issue from technological and organizational spheres with different perspectives but paid scant attention to humans' roles during the process. Acknowledging the power of human in organizational technology adoption, this paper started from the proposition that the balance among human, organization, and technology spheres is a significant and holistic perspective to explain the heterogeneous BIM adoption performance in even similar organizations. Based on a prior work that developed the theoretical Human-Organization-Technology (HOT) fit model, this paper aimed to uncover the influencing factors of the HOT fit. It contextualized the theoretical model to CPO's BIM adoption and developed an operationalization methodology with SNA and comparative case study to measure the HOT fit index. Using empirical data collected from 14 BIM project and 6 non-BIM projects, it calculated the HOT fit index of the 14 BIM projects and furtherly analyzed how it can be impacted by potential organizational and technological factors.

The research found that project size is directly, significantly, and negatively related to HOT fit. When it is joined by hierarchy steepness, BIM LOD, or both, the correlations between the joint factors and HOT fit are also significant. Project size is also found to have a direct, significant, and negative relation with Human-Technology (HT) fit and Organization-Technology (OT) fit. Hierarchy steepness is directly, significantly, and positively related to HT fit, OT fit, and Human-Organization (HO) fit. BIM LOD is only found to have a direct, moderate, and negative relation with OT fit. Also, the combination of hierarchy steepness and project size is related to HT fit and HO fit. The combination of project size and BIM LOD is associated with HT fit and OT fit. The joint of hierarchy steepness, project size, and BIM LOD is also related to HT fit, OT fit, and HO fit. Interestingly, the combination of hierarchy steepness and BIM LOD is statistically related to the HT fit, OT fit, and HO fit but not the HOT fit.

Based on the findings, it further discussed how humans, organizations, and technologies could adapt to HOT fit for better BIM adoption. For organizations, strategies to improve HOT fit include steepening the organizational hierarchy structure and developing a progressive BIM adoption strategy to achieve desired HOT fit. Technologies should be adapted for HOT fit with specific solutions for different projects and scenarios. Nevertheless, a word of caution is that the research is by no means to develop a prescribed BIM adoption therapy. BIM adoption is rather complicated. The HOT fit model can be perceived as an analytic framework through which humans, organizations, and technologies can be better analyzed to catalyst the harness of BIM's power.

This research has four major unique contributions to the engineering management domain. Firstly, it sheds light on 'human' and emphasizes the significance of 'human' in engineering management. Secondly, it developed the holistic HOT fit model for BIM adoption in construction project organizations and studied the factors influencing the HOT fit. Thirdly, it proposed the new methodology to measure the HOT fit level quantitatively with passively left behind project records. Finally, it unexpectedly discovered that steeper hierarchy structure is beneficial for HOT fit, which contradicts to previous arguments of organization structure steepness. Even though, it also has some limitations that awaits future research to explore through: (1) incorporating more influencing factors into the analysis; (2) validating the HOT fit model with cases from different BIM project types; (3) studying BIM project cases from different organization types; (4) conducting longitudinal analysis to investigate the dynamics of HOT fit during the project lifecycle; and (5) linking HOT fit level with project performance.

Data Availability Statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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Table 1. Benefits and hurdles of BIM adoption

Aspects	Benefits	Reference	Hurdles	Reference
General	Better customer service	5	Fragmented nature of construction industry	10
	Superior project performance	11	Unclear and invalidated benefits of BIM in ongoing practices	5
	Better production quality	5	Lack of familiarity with BIM adoption	3
	Integrated procurement	8	Ownership/intellectual property of the BIM data and its copyright	5
	Lifecycle information management	5, 8	Missing insurance framework for BIM application	5
	Controlled whole-life costs	5, 8	Contractual environment	5
	Reducing costs and improving the accuracy and speed of cost estimates	5	Insufficient research on the correlation between influential factors and BIM utilization	4
			Lack of protocols	3
			Cybersecurity and reliability of building information	5
			Lack of sufficient legal framework for integrating owners' view in design and construction	5
			Extra cost of training, specialized software, and hardware upgrades	3, 5
Human	Facilitate concurrent communication between different stakeholders at different phases	2	Need to educate professionals about BIM	5
			Habitual resistance to change	5
	Foster the multi-disciplinary collaboration	1	Lack of supporting education and training for the use of BIM	5
	Reduced conflict	6	Not familiar enough with BIM capabilities	3, 5
			Lack of managers' and owners' awareness and support	5
			Unclear roles and responsibilities for loading data into a model or databases and maintaining the model	3
Organization and organizing	Integrate separate tasks including estimating, scheduling, and spatial coordination more effectively	2	Lack of effective collaboration between project stakeholders for modeling and model utilization	3
	Controlled digital data management environment	4, 5	Changes in workflow and inappropriate business model	3
	Coordinated, consistent, and computable building lifecycle information/knowledge management	4	No well-developed practical strategies and standards	5
	Faster and more effective processes	7	Organizational structure that does not support BIM	3
	More (and better) decision-making information earlier	5	Lack of cooperation from other industry partners	5
	Reduce requests for information and change orders	5	Responsibility between stakeholders	5

	Automated generation of construction documents	5		
Technology	Technical superiority	8	Functionality of BIM tools	5
	Simulation and visualization of the construction project	5	Lack of supporting resources (software, hardware) to use BIM tools	3
	Interoperability capabilities	8	Requirements of computable digital design data	5
	Better design, fewer clashes	5,8	Need for sophisticated data management	5
	Accurate geometrical representation	5	Lack of data interoperability	5
	Early building information capture	8		
	Better early-phase analysis	5		
	Automated assembly	9		

Note: References 1 (Singh et al., 2011), 2 (Becerik-Gerber et al., 2012), 3 (Chien et al., 2014), 4 (Lee et al., 2015), 5 (Sun et al., 2015), 6 (Charehzehi et al., 2017), 7 (Ghaffarianhoseini et al., 2017), 8 (Ahmed & Kassem, 2018), 9 (Dawod & Hanna, 2019), 10 (Kim et al., 2020), 11 (Lu et al., 2020)

Table 2. Referencing relationship between the BIM and Non-BIM projects

Referenced Non-BIM projects					**Referring BIM projects**				
Proj. ID	**Gross site area (m^2)**	**Contract sum (HKD)**	**Flat no.**	**Detailed facility type**	**Proj. ID**	**Gross site area (m^2)**	**Contract Sum (HKD)**	**Flat no.**	**Detailed facility type**
N1	23,955	1,927,135,820	5204	6 residential buildings, a 3-story commercial center, a 1-story car park	B3	17,258	831,184,737	2002	2 residential buildings, a 4-story car park and a 7-story commercial center
					B5	84,823	4,711,780,000	7143	9 residential buildings, a commercial center and a car park
					B6	28,817	2,106,166,521	3494	4 residential buildings and a commercial center
					B8	46,187	2,467,000,000	3311	7 residential buildings, a 3-story car park and a 2-story ancillary facilities block
					B10	26,200	1,342,934,239	3039	5 residential buildings and a 2-story car park
					B11	69,808	2,478,381,802	3459	5 residential buildings, a 5-story ancillary facilities block, a 3-story commercial center, a lift tower, a market, a public transport interchange

					B12	64,127	4,828,996,401	4625	8 residential buildings, a 2-story car park and a 3-story car park
					B13	35,489	1,440,746,981	2097	4 residential buildings and a 1-story commercial center
N2	10,188	688,800,000	1390	2 residential buildings and a 5-story ancillary facilities block	B7	11,871	745,400,000	1358	2 residential buildings and an ancillary facilities block
N3	9,894	523,308,000	1488	2 residential buildings	B9	32,412	2,888,000,000	3480	6 residential buildings
					B14	28,473	1,515,849,003	2808	5 residential buildings
N4	10,197	468,525,558	1216	1 residential building and a 4-story car park	B1	18,171	550,718,934	2524	3 residential buildings and a 5-story car park
N5	11,950	538,700,000	990	2 residential buildings and a 2-story community hall	B4	12,000	485,040,981	990	1 residential building
N6	25,124	717,458,250	857	1 residential building	B2	6,097	797,332,380	567	1 residential building

Table 3. Number of professionals involved in each BIM cases

Project ID	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14
No. of Professionals	50	37	46	45	33	36	41	41	30	45	39	34	36	32

Table 4. Fit indexes and project-level variables of different BIM cases

Project ID	**HOT fit index**	**HT Fit Index**	**OT fit index**	**HO fit index**	**Organization characteristics**		**BIM characteristics**	
					Hierarchy steepness	**Project size (Hong Kong dollar)**	**BIM LOD**	**BIM Application Scenario**
B3	0.26666	0.05614	0.02473	192.04	12.3948	831,184,737	LOD350	Clash analysis; spatial checking; design refinement; building service coordination.
B2	0.23105	0.02725	0.03455	245.44	11.7941	797,332,380	LOD300	4D simulation of demolition of precast building.

B13	-0.00278	0.0009	-0.0368	83.91	11.5205	1,440,746,981	LOD350	3D visualization; clash analysis; 4D construction sequence for construction activities
B1	-0.00676	0.00076	-0.0216	409.18	12.3483	550,718,934	LOD200	3D view of design; tender documentation.
B6	-0.01938	0.00574	-0.0143	236.05	11.3418	2,106,166,521	LOD200	Environmental/visual design simulation
B10	-0.02541	0.00255	-0.023	434.46	12.2569	1,342,934,239	LOD350	BIM for QS, 5D cost management
B9	-0.32237	-0.0503	-0.0517	123.89	11.8608	2,888,000,000	LOD300	4D simulation of demolition; sustainable construction
B7	-0.36517	-0.03459	-0.0557	189.63	11.6149	745,400,000	LOD350	3D visualization; clash analysis; design option analysis; building service coordination
B14	-0.47676	-0.08992	-0.0743	71.35	11.2104	1,515,849,003	LOD350	3D visualization; clash analysis; 4D construction sequence for construction activities
B11	-0.57012	-0.05306	-0.0853	126.01	11.4578	2,478,381,802	LOD350	Safety measures planning; clash analysis; 4D construction simulation
B8	-1.1525	-0.04636	-0.0814	305.31	11.9606	2,467,000,000	LOD300	4D simulation of demolition; sustainable construction
B4	-1.80495	-0.09179	-0.1812	108.52	11.8058	485,040,981	LOD400	Site layout planning; safety planning; clash analysis; 4D simulation of construction activity; installation collaboration.
B5	-3.47093	-0.09679	-0.1439	249.22	11.2826	4,711,780,000	LOD350	3D visualization; clash analysis; 4D scheduling of progress, resources, and prefabrication; 5D cost management.
B12	-3.66988	-0.09514	-0.1465	263.32	11.403	4,828,996,401	LOD350	Safety measures planning; clash analysis; 4D construction simulation

Table 5. Results of regression between characteristics and fit index

	Mean	SD	HS	PS	BL	HS and PS	PS and BL	HS and BL	HS, PS, and BL
HT fit	-0.0332	0.0133	0.6047**	0.5712**	0.4107	0.6761**	0.6760**	0.6803**	0.7445**
OT fit	-0.0612	0.0170	0.4586*	0.5151*	0.4868*	0.5621	0.6793**	0.6181*	0.6983*
HO fit	217.024	30.145	0.5389**	0.0253	0.4509	0.6449*	0.4557	0.6504**	0.7406**
HOT fit	-0.8135	0.3457	0.4445	0.7812****	0.3591	0.7827***	0.8336**	0.5292	0.8337***

Note: SD (Standard deviation), HS (Hierarchy Steepness), PS (Project Size), BL (BIM LOD);
* $0.05<p<0.1$; ** $0.01<p<0.05$; *** $0.001<p<0.01$; **** $p<0.001$.

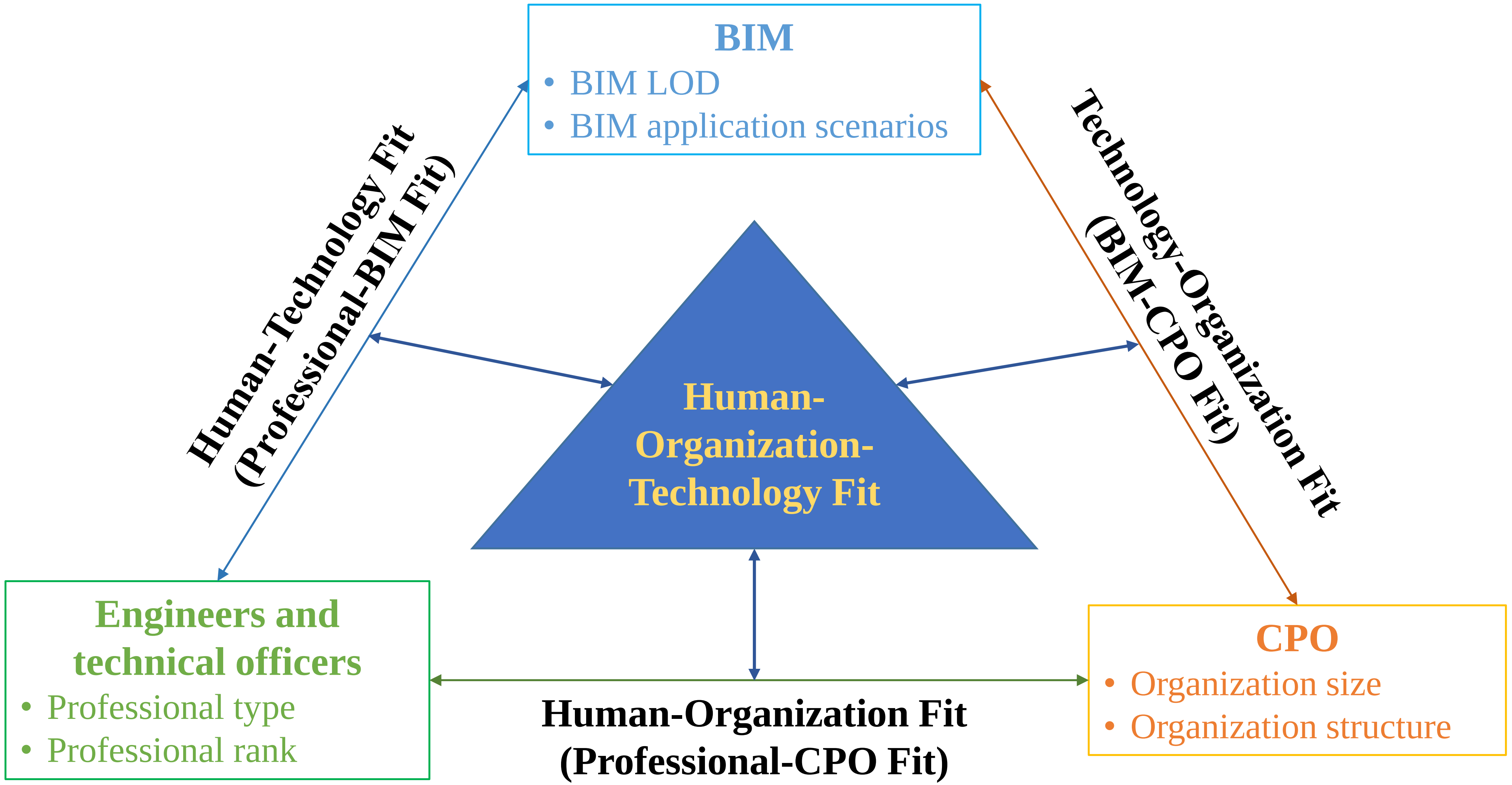
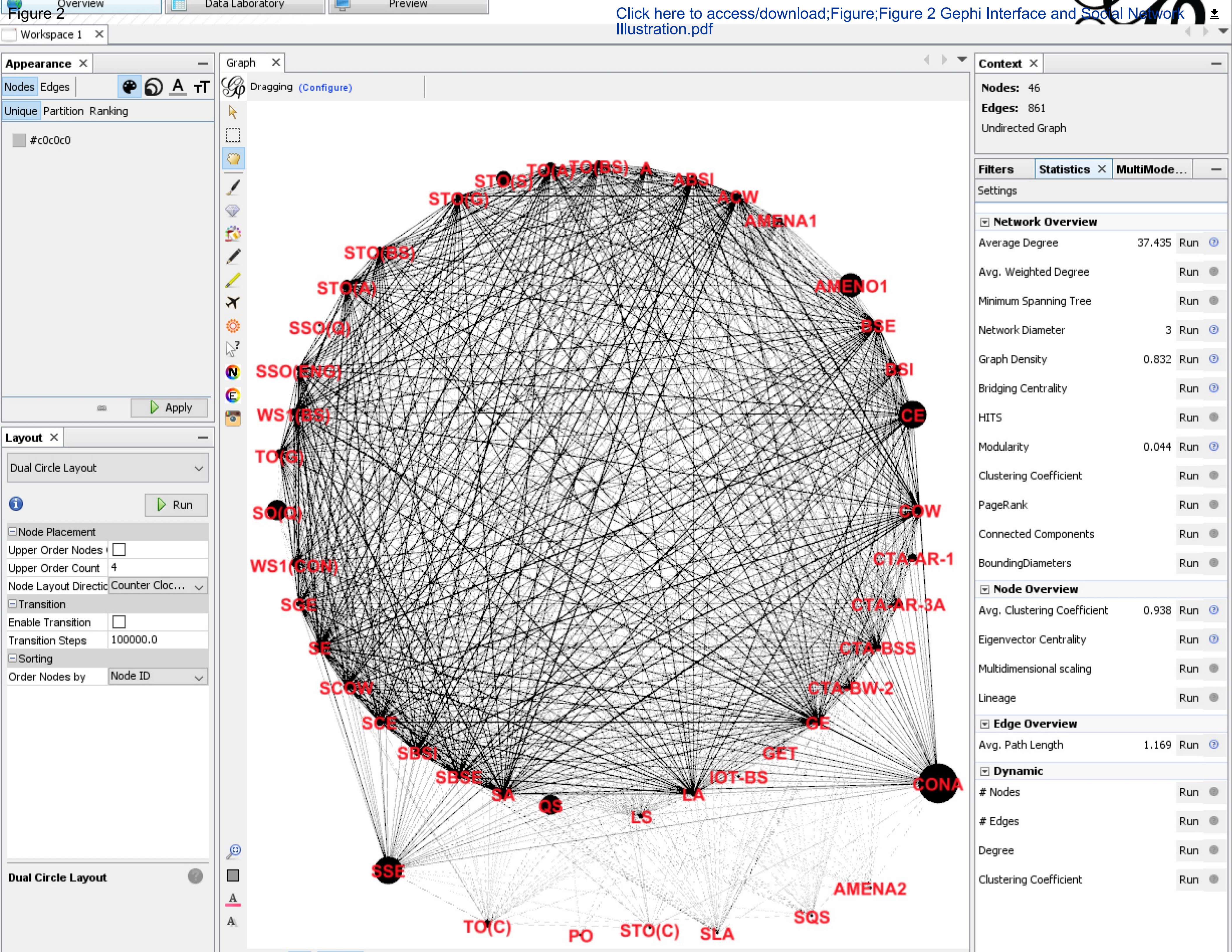

BIM
• BIM LOD
• BIM application scenarios
Human-Technology Fit
(Professional-BIM Fit)
Technology-Organization Fit
(BIM-CPO Fit)
Human-Organization-Technology Fit
Engineers and technical officers
• Professional type
• Professional rank
Human-Organization Fit
(Professional-CPO Fit)
CPO
• Organization size
• Organization structure

Figure 2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Preview
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Dual Circle Layout
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CTA-AR-3A
CTA-BSS
CTA-BW-2
SSE
TO(C)
PO
STO(C)
SLA
SQS
AMENA2
Context
Nodes: 46
Edges: 861
Undirected Graph
Filters
Statistics
MultiMode...
Settings
Network Overview
Average Degree 37.435 Run
Avg. Weighted Degree Run
Minimum Spanning Tree Run
Network Diameter 3 Run
Graph Density 0.832 Run
Bridging Centrality Run
HITS Run
Modularity 0.044 Run
Clustering Coefficient Run
PageRank Run
Connected Components Run
BoundingDiameters Run
Node Overview
Avg. Clustering Coefficient 0.938 Run
Eigenvector Centrality Run
Multidimensional scaling Run
Lineage Run
Edge Overview
Avg. Path Length 1.169 Run
Dynamic
Nodes Run
Edges Run
Degree Run
Clustering Coefficient Run