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# Perceived benefits of and barriers to Building Information Modelling (BIM) implementation in construction: The case of Hong Kong

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ABSTRACT

BIM has experienced an increasing appeal in its adoption and implementation in the built environment worldwide in recent years. The current research study aims to identify and assess the perceived benefits of and barriers to BIM implementation in the Hong Kong construction industry. The study adopted a quantitative research design using a structured empirical questionnaire survey. Also, a comparative analysis of the perceptions of the respondents' groupings was conducted. The major barriers to BIM adoption are related to the inherent resistance to change by construction stakeholders, inadequate organizational support and structure to execute BIM, and lack of BIM industry standards in Hong Kong. Meanwhile, the key benefits include better cost estimation and control, efficient construction planning and management, and improvement in design and project quality. Practical and insightful recommendations were suggested for policymakers, local authorities, construction firms, and other key stakeholders to increase the uptake of BIM in construction projects as well as to aid them in the quest for full adoption of BIM in the built environment. The practical implications of the research findings were also presented and discussed.

## 1. Introduction

The adoption and implementation of BIM are steadily increasing in the built environment [1]. One of the key reasons for BIM adoption is to maintain a proper balance among the project management triangle of scope (features & quality), cost and time [2,3]; which is one of the vital concerns of clients in the architecture, engineering, and construction (AEC) industry. Meanwhile, through the adoption and implementation of BIM in a building project, Wong et al. [4] believed that project stakeholders could maximize benefits regarding time, cost, and quality. However, it is not easy to achieve a right balance between these three factors for the construction projects, since so many strategies and solutions are needed to accomplish it, and innovation can be one of the possible solutions to strike a balance between these three factors.

Therefore, innovative technology is a salient topic nowadays, and Building Information Modeling (BIM) has become the cynosure of all eyes in the recent development of the construction industry [5]. Abanda et al. [6] described BIM as a "global digital technology" which had brought about a revamp of the structure and processes of the construction industry. The Hong Kong Construction Industry Council (CIC) report [7] outlined the possibilities brought along by BIM to the construction project phases, which includes it is innovative and user-friendly features among others. The CIC report further emphasized the dynamism of the BIM innovation and its creation of a new paradigm shift in the construction industry. Smith and Tardif [8] also observed the contribution of BIM to improving communications among business partners at the conceptual stage, and the overall reduction in the cycle time as well as the life cycle cost of a project.

The Hong Kong Institute of Building Information Modeling [9] defined BIM as "the process of generating and managing building data during its life cycle [which typically] uses three-dimensional, real-time, dynamic building modeling software to increase productivity in building design and construction." Also, the CIC [7] stated that BIM is not just a "three-dimensional drawing tool but a new tool to holistically manage information relating to construction projects from the preparatory stage to construction and operational stages." CIC [7] further expressed BIM as a "new way of working, using new technology to facilitate project management and execution, better construction process control, cross-disciplinary collaboration, internal coordination, external communication, problem-solving, and risk management." From the above definitions, it can be concluded that Building Information Modeling is not just a designing tool but a system to manage the project during its life cycle.

Despite some mileage reached in the adoption of BIM in the Hong

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Kong construction industry, Cao et al. [10] noted that its BIM development is still at the primitive stage and calls for future research to extend its findings into the barriers to its implementation. More so, Kori and Kiviniemi [11] observed that some tangible benefits such as efficient construction delivery had been achieved in countries such as the United States, the United Kingdom, Australia, Singapore, Hong Kong, The Netherlands among others during BIM adoption. However, the study did not explore the perceived benefits in the stated countries in-depth. The first study on BIM adoption in Hong Kong was conducted thirteen years ago by Tse et al. [12] which revealed a very low adoption of BIM in Hong Kong due to lack of demand by clients. Since the study by Tse et al. [12], BIM adoption has increased in Hong Kong [13]. Also, the position of Hong Kong as Asia's financial hub and its influence on the Mainland China's construction industry, adds further significance to various studies exploring the execution of innovative techniques in the Hong Kong construction industry.

Given the above perspective, the current study aims to identify and assess the perceived benefits of and potential barriers to BIM implementation in Hong Kong's built environment. The perspective of key stakeholders in Hong Kong's construction sectors such as the clients, contractors, BIM managers, etc. will be solicited in data collection. The study will also attempt a comparative analysis of the perceptions of the respondents' groups on each identified factor (benefits and barriers). The findings of the study are expected to be useful for policymakers, government departments, construction organizations, and other key stakeholders in their quest to improve the current uptake of BIM in various construction projects. The paper will also discuss the current process to develop a BIM standard for the Hong Kong construction industry spearhead by the Hong Kong Construction Industry Council (CIC). Also, the practical implications of the research findings will be highlighted as well as effective recommendations on how the full implementation of BIM can be achieved in the construction sector.

This paper is structured as follows. Section 1 introduces the background of study and the concept of BIM implementation. Section 2 reviews the adoption of BIM in both Hong Kong and other developed economies, and Section 3 discusses the adopted research designs and the statistical tools employed in the study. Section 4 highlights the study's significant findings and discusses the perceptions of the diverse groups of survey participants. Section 5 encapsulates the practical implications of the study while Section 6 concludes the study and provides useful recommendations for augmenting the uptake of BIM in Hong Kong.

## 2. Development and implementation of BIM in developed regions

The concept of BIM was initiated by Charles M. Eastman in the 1970s and started growing from the 1980s in the European countries [14]. Moreover, in recent years, its implementation and adoption have become widespread in some developed countries such as the United States, the United Kingdom, Norway, Finland, Sweden, Denmark, Singapore and Hong Kong [15]. Bernstein et al. [16] reported that rapid growth in its global appeal and that a broader set of construction companies have committed resources towards the adoption and implementation of BIM for their construction projects.

To this end, several governments and professional bodies have advocated the use of BIM in the AEC industry to facilitate more cooperation and coordination among various project stakeholders while ensuring project quality and affordable service [17]. The recent rise in its utilization in countries like the United States, the United Kingdom, Australia had resulted in more in-depth research into BIM and other knowledge domain areas associated with the construction project processes such as safety management, project management, facility management amongst others [13,18]. Indeed, the development and affordability of ICT services had facilitated in its adoption in several countries, with variants such as mobile BIM and cloud BIM, representing a gradual shift from the desktop-based BIM processes [19]. However, the non-availability of BIM standards in some of these countries is still a disadvantage [20,21].

Meanwhile, the rate of adoption of BIM by various disciplines or professional bodies differs in these countries with more approval by architects, engineers and less by facility managers and quantity surveyors/estimators. Aibinu and Venkatesh [22] and Von Both et al. [23] observed that BIM in Australia and New Zealand focused mostly on 2D and 3D collaboration rather than integration of the whole BIM processes. In New Zealand, cost estimation is carried out based on 2D-drawings [23], while in Australia, Aibinu and Venkatesh [22] reported a low adoption of BIM by Australia's quantity surveyors. One of the factors attributed to the low adoption in Australia was the “lack of trust in the integrity of BIM” and “lack of demand by the clients” among other barriers.

Survey reports and studies by Von Both et al. [23] in Germany, Gerrard et al. [24] in Australia, Arayici et al. [25] in the United Kingdom and Ku and Taiebat [26] in the United States, revealed several barriers to adoption of BIM in these countries. These barriers span from lack of BIM expertise, interoperability, resistance to change, to the cost of company investment. However, Yan and Damian [27] found out that the United States firms in the AEC industry utilize more BIM for their projects than other AEC industries elsewhere in the world. In the United Kingdom, the government bill on BIM has made it mandatory for public sector projects staring from the year 2016 [22].

### 2.1. BIM adoption and implementation in Hong Kong

BIM implementation is still at the germinating stage of development in the Hong Kong construction industry. Some companies are fast movers and have widely adopted this technology; while some are still observing the development and success of BIM [7]. A survey by Tse et al. [12] revealed the lack of demand by project stakeholders and clients as the significant factor hindering the implementation of BIM in Hong Kong, and they concluded that the adoption rate is very low in Hong Kong and that industry professionals still prefer the traditional CAD software. Khodeir et al. [28] discussed the integration of BIM tools for the sustainable retrofitting of heritage buildings. Tables 1 and 2 elicit the common barriers to and benefits of BIM implementation used in this study based on a desktop review of the extant literature.

In the public sector, the Airport Authority of Hong Kong, Hong Kong Housing Authority, and Mass Transit Railway Corporation (MTRC) have started using BIM system for their projects. The Buildings Department has also launched a consultancy study concerning the feasibility of implementing an electronic system for the approval of drawing submissions [7]. If it is feasible, it will be a revolutionary change of design support in the whole industry [14]. In the private sector, some property developers in Hong Kong have already adopted BIM in their construction projects. Wong et al. [4] observed that these fast movers have played a vital role in promoting BIM in Hong Kong because they not only establish their own in-house BIM departments, but they also employ external BIM consultants to provide tailored-made BIM services.

A communique of the Hong Kong Institute of Building Information Modelling (HKIBIM) and the Hong Kong Construction Industry Council (CIC) announced a new phase in the Hong Kong AEC industry in which automation in construction will be a leading trend in the coming future of Hong Kong. The communique further attributed it to its endorsement and adoption of BIM as a new approach for facilitating project execution as well as project management. Two working groups including “the Working Group on Roadmap for BIM Strategic Implementation” and “the Task Group on Establishment of Industry Standards for BIM Implementation” were established by the Hong Kong Construction Industry Council (CIC) to work towards the strategic development and implementation of BIM in Hong Kong.

Moreover, to keep pace with the global trend in BIM, the Hong Kong SAR Government has adopted BIM technology in public sector projects since the year 2006. For instance, the Hong Kong Housing Authority

**Table 1**
Summary of literature on the barriers to BIM implementation.

| Barriers to BIM Implementation | Description | References |
|---|---|---|
| 1. High initial cost | The cost of procuring the BIM software and licenses, hardware and other associated cost related to BIM start-up usage | [4,22,29–34] |
| 2. Lack of expertise | The non-existent of competent project staff with previous experience on BIM implementation | [4,21,22,30,31,33,35–40] |
| 3. Insufficient interoperability of computer software | The loss of data and information in BIM models due to incompatibility among the BIM software and data schema | [6,29–31,33,34,38–41] |
| 4. Lack of training/courses | The non-availability of training programs to facilitate the transfer of knowledge on BIM | [4,21,22,33,36,42] |
| 5. Cultural barrier (resistance to change) | The apathy of project stakeholders to change from the conventional (2D) ways of managing project and designs. | [31,33,38–40,42–44] |
| 6. Poor collaboration among project participants | The low level of information sharing and coordination among project team members and in the industry. | [31,33,43,44] |
| 7. Organizational structure that does not support BIM | The non-existent BIM units or department within organizations to support its practice and deployment | [4,31,33,45,46] |
| 8. Lack of subcontractors who can use BIM technology | Non-existent of BIM-compliance subcontractors to facilitate its use in the industry | [31,34,45,46] |
| 9. Security risk | Issues arising because of the risk of losing intellectual property right of BIM models | [20,30,31,34,47] |
| 10. Lack of industry standards | Non-availability of BIM standards, codes and regulation to facilitate BIM implementation | [4,20,21,31,33,34,36,38] |
| 11. Difficulties in measuring the impacts of BIM | The arduous task involved to independently and exclusively assess the influence of BIM on project success. | [22,26,31,33,34] |
| 12. Shortage of BIM implementation data in the construction phase | The reduction and insufficient level of detail (LOD) in the BIM model used in the construction stage. | [4,31,48,49] |

(HKHA) has introduced BIM in its development of public rental housing projects, and it has more than nineteen (19) projects which have already adopted BIM technology [7]. Another example is that the Highways Department has pioneered the application of BIM technology with the Tuen Mun Road Project and the Central-Wan Chai Bypass Project [7]. Meanwhile, based on the desktop literature, key factors that influence the top management of firms to adopt BIM include its ability to enhance the competitiveness in the market and facilitate the business operation [8]. Utilizing the innovative tools can help the firms to maintain their competitiveness within the industry because BIM can improve project quality and minimize the risks as well as the cost of the construction projects [50]. Particularly in Hong Kong, the sustainability issues have become increasingly important [51,52], and building owners can make use of the data generated from BIM to manage and upkeep their buildings for the optimization of energy consumption [53]. Therefore, it is not difficult to conclude that the use of BIM will be the rising trend in Hong Kong for both public and private sectors.

Although the benefits of BIM is quite evident in the construction industry, the adoption of BIM has not yet spread as fast as expected because of some potential barriers [3,54]. For instance, the adoption of technology confronts both technical and non-technical issues. Regarding the technical problems, they lack industry protocols and insufficient interoperability of computer software [3,55]. Regarding the non-technical issues, they include the cultural barrier (resistance to change), the change of practice workflow among others [56]. Therefore, to facilitate the BIM adoption in the Hong Kong construction industry, it is essential to fully understand the key benefits and major barriers for implementing BIM from the views of different industrial practitioners [4].

## 3. Research methodology

This study evaluated the opinions of core project stakeholders in the Hong Kong AEC industry about the major barriers to BIM implementation in Hong Kong and the key benefits derivable from BIM implementation. A quantitative research method was employed which involved soliciting the perceptions of key stakeholders in the Hong Kong construction industry via a structured empirical questionnaire

**Table 2**
Summary of literature on the benefits of BIM implementation.

| Benefits of BIM Implementation | Description | References |
|---|---|---|
| 1. Improve project quality | BIM implementation improve project quality variables by facilitating the ease of assessment of construction materials and work process | [4,22,27,53,54,57–61] |
| 2. Better understanding of design | The application of n-dimension (3D) could ease the ability of the project team to visualize and understand the design by using some essential functions like “rendering” and “walk-through. | [4,26,39,41,46,53,54,61] |
| 3. Provide life cycle data | The information generated by the BIM system can be utilized in the whole life cycle of the project. | [26,41,53,61,62] |
| 4. Scope clarification | BIM is an appropriate tool to check clashes and reduce discrepancies among design drawings. | [4,22,54,63–65] |
| 5. Speed up the design process | BIM ease the process of the project design earlier to ensure all stakeholders understand and approve the design earlier. | [4,26,39,41,46,53,62,66] |
| 6. Reduce construction cost | BIM model can facilitate effective site planning to enhance efficiency as well as reduce the rework to save time and money | [4,22,27,41,46,54,57,60,61] |
| 7. Better cost estimates and control | BIM can generate some data including the quantities of materials automatically which can increase the accuracy of the cost estimate and control compared to the manual measurement | [4,26,41,53,54,61,62] |
| 8. Better construction planning and monitoring | BIM system can display a very clear full picture of the project and show the work sequences on a computer before the actual commencement of the project on-site | [4,22,46,53,54,57,61,67–69] |
| 9. More efficient communications | The BIM system facilitates and eases the process of knowledge-sharing and coordination in the industry. | [4,22,41,48,54,61,69,70] |
| 10. Reduce project duration | BIM facilitates the delivery of a construction project on or before schedule. | [4,27,53,54,57,60,69] |
| 11. Improve safety performance | BIM system facilitates the integration of safety precaution and variables which can be simulated to improve safety on site. | [54,58,59,61,71,72] |
| 12. Enhance organizational image | An organization policy or strategy toward integrating and implementing BIM in their work processes can improve their competitive advantage. | [4,53,55,73] |

survey. The study was conducted via the lens of a post-positivism research paradigm [74], with a mix of deductive and inductive reasoning in arriving at the questionnaire items (benefits and barriers); while a deductive approach was applied for the rest of the study. The study adopted a purposive sampling technique [3] in the selection of target survey respondents. Meanwhile, to avoid bias by the survey participants, as also emphasized by Trochim [75] who observed that research measurements are fallible and respondents inherently biased; the study utilized triangulation technique to achieve some measures of objectivity through the use of multiple statistical measures [75]. The target respondents for the current study include clients, developers, main contractors and BIM consultants operating within Hong Kong and with practical hands-on BIM experience in their construction projects. The identified factors (benefits and barriers) were deduced through the means of a desktop literature review of journal papers, HKIBIM-CIC BIM Conference Proceedings, and online materials. The questionnaire survey forms the basis for assessing the respondents' perceptions. The respondents were obliged to identify and rank the identified benefits of and barriers to BIM implementation in Hong Kong on a five-point Likert-type scale, which was later used to measure their levels of agreement.

The questionnaire also solicited background details regarding the survey participants' years of professional working experience in the construction industry and the number of BIM projects they have participated. Since all the survey participants were well-experienced professionals with requisite BIM knowledge in the construction sector, their opinions gathered were considered reliable and representative, and reflected the true perceptions of BIM practices in the construction industry. Other details include the type of organization they are employed and their position within the organization. A total of 62 questionnaire surveys was distributed to the target respondents who have been engaged in BIM projects via a purposive sampling technique. The questionnaire survey was returned with 44 completed and valid questionnaires after a month representing an effective response rate of 71%. The sample size of this study (44 responses) was considered satisfactory and adequate for various types of statistical analysis conducted when compared with other studies which have utilized similar purposive sampling techniques, e.g. Ameyam and Chan [76] with 40 responses; Osei-Kyei and Chan [77] with 42 responses; Chan et al. [78] with 45 responses. So, the chosen sample was regarded as reliable and substantially representative of the survey population.

### 3.1. Methods of data analysis

Data analysis is a process of deriving significant facts, details or seek an interpretation of raw statistical data in its vague form [79]. This study employed five common statistical analysis tools to analyze the collected data from the questionnaire survey and to compare the views between groups of respondents. These include the Cronbach's alpha reliability test, mean score ranking method, Kendall's concordance analysis, Spearman's rank correlation test, and Mann-Whitney U test.

### 3.2. Reliability testing

The Cronbach's alpha reliability test is mainly used to verify the internal consistency or reliability of the construct of the questionnaire items under the adopted Likert scale of measurement [79–81]. The range of the Cronbach's alpha coefficient is from 0 to 1. The larger the α-value, the higher the reliability of the generated result or scale will be. If the α-value ≥ 0.7, the measurement scale is reliable [81–83]. Table 3 depicts the alpha values for this study. These alpha values reveal that the questionnaire items are closely related, reliable and significant at < 5%; hence further analysis was conducted on the set of data gleaned.

**Table 3**
Reliability analysis for the components of this study.

| Questionnaire components | Alpha value |
|---|---|
| Barriers to BIM implementation in Hong Kong | 0.717 |
| Benefits of BIM implementation in Hong Kong | 0.771 |

**Table 4**
Demographics of survey respondents.

| Respondent demographics | Percentage (size) |
|---|---|
| Type of organization | |
| Clients | 32% (14) |
| BIM Consultants | 27% (12) |
| Contractors | 41% (18) |
| Years of working experience in the AEC industry | |
| 0–5 years | 9% (4) |
| 6–10 years | 36% (16) |
| 11–15 years | 32% (14) |
| More than 15 years | 23% (10) |
| Experience with BIM-enabled construction projects | |
| 1–2 projects | 7% (3) |
| 3–4 projects | 27% (12) |
| 5 projects or more | 66% (29) |

## 4. Analysis and discussion of survey findings

This section presents the data collected during the study's questionnaire survey and discusses the findings of the statistical tools utilized in the study. The characteristics of the respondents' demographics were solicited in Section A of the study questionnaire and as presented in Table 4. The set of survey participants are from diverse organization setup: the majority are from the contractors constituting 41%, followed by the client organizations (32%) and the BIM consultants' group (27%). The diversity in the respondents' groups allows for the capturing of the differing viewpoints of the survey participants. Moreover, on average, the respondents have gained more than ten years of working experience in the construction industry. However, only 9% of the survey participants have less than five years of working experience. The data analysis establishes the fact that the respondents have not just theoretical knowledge of the workings of the AEC industry but have over the years bring such knowledge into practice.

The target respondents for the questionnaire survey were mainly those with at least a year experience in BIM-enabled projects. The majority of them (66%) are involved in more than 5 BIM-enabled projects, 27% have direct hands-on experience in 3–4 BIM projects, and just 7% have managed 1–2 BIM projects. In summary, the relative experience and competence of the survey participants are adequate and can be relied upon as a representative of the actual population and give credibility to the survey data collected.

### 4.1. Barriers to BIM implementation in Hong Kong

#### 4.1.1. Ranking results

The survey results of the ranking of the barriers to BIM implementation are presented in Table 5. For the 12 identified barriers, the mean (M) values range from the lowest mean score of M = 2.77 "Poor collaboration among project participants" to the highest mean value of M = 4.39 "cultural barrier (resistance to change)." The three most significant barriers are related to senior management commitment and technology issues; and these include: cultural barrier (resistance to change) (M = 4.39) [42]; an organizational structure that does not support BIM (M = 4.27) [33], and insufficient interoperability of computer software (M = 4.07) [6,30,38].

Most of the respondents aligned to the fact that the slow adoption of this innovative approach [3] has affected the incorporation of construction management techniques which increases the current workload

**Table 5**
Barriers to BIM implementation in Hong Kong.

| Barriers to BIM Implementation | All Respondents | | Client Group | | Consultant Group | | Contractor Group | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Rank | Mean | Rank | Mean | Rank | Mean | Rank |
| Cultural barrier (resistance to change) | 4.39 | 1 | 4.29 | 2 | 4.33 | 1 | 4.50 | 2 |
| Organizational structure that does not support BIM | 4.27 | 2 | 4.00 | 3 | 4.17 | 2 | 4.56 | 1 |
| Insufficient interoperability of computer software | 4.07 | 3 | 4.43 | 1 | 3.67 | 3 | 4.06 | 3 |
| Lack of industry standards | 3.61 | 4 | 3.50 | 4 | 3.42 | 4 | 3.83 | 4 |
| Difficulties in measuring impacts of BIM | 3.48 | 5 | 3.50 | 4 | 3.42 | 4 | 3.50 | 5 |
| Shortage of BIM implementation data in construction phase | 3.39 | 6 | 3.36 | 8 | 3.33 | 6 | 3.44 | 6 |
| Security risk | 3.30 | 7 | 3.07 | 10 | 3.33 | 6 | 3.44 | 6 |
| Lack of expertise | 3.23 | 8 | 3.50 | 4 | 2.92 | 10 | 3.22 | 9 |
| Lack of training/courses | 3.20 | 9 | 3.21 | 9 | 2.83 | 11 | 3.44 | 6 |
| High initial cost | 3.18 | 10 | 3.43 | 7 | 3.08 | 8 | 3.06 | 11 |
| Lack of subcontractors who can use BIM technology | 2.98 | 11 | 2.64 | 12 | 3.08 | 8 | 3.17 | 10 |
| Poor collaboration among project participants | 2.77 | 12 | 2.93 | 11 | 2.58 | 12 | 2.78 | 12 |

of professional staff and workers. Also, most of the respondents perceived that the development of BIM without changing some aspects of the organizational structures and strategies [4,33] might not motivate the staff to learn and apply this technology for their work. Furthermore, the survey participants believed that it might increase the time and cost of information exchange and communications among project stakeholders if there is an insufficient interoperable environment. Overall speaking, the level of consensus between these three groups is very high because the three most significant barriers are both included in the top 3 items in these three groups.

#### 4.1.2. Ranking agreement within each respondent group

The Kendall's coefficient of concordance (W) was employed to measure the agreement of different respondents on their rankings regarding the barriers to BIM implementation based on mean values within a particular group [3,17]. The Kendall's coefficient of concordance measures the agreement of the various respondents based on mean values within a certain group [84]. The range of the value of Kendall's coefficient of concordance (W) is from 0 to 1. The higher the value of W, the higher the level of consensus among the survey respondents within the group [85,86]. If the number of items to be ranked is larger than 7, chi-square analysis should be applied instead [87].

The null hypothesis ($H_0$) states that "*the survey respondents' sets of rankings are unrelated or independent to each other within a study group*." The rule is that if the calculated chi-square value equals or is greater than the critical value from the table showing a particular level of significance and value of degrees of freedom, $H_0$ will be rejected. In other words, there is a significant degree of agreement on the rankings of the items among the survey respondents within the group.

The value of W is as follows:

$$W = \frac{\sum_{i=1}^{n} (\bar{R}_i - \bar{R})^2}{n(n^2 - 1)/12}$$

where n = number of items ranked; $R_i$ = average of the ranks assigned to the ith item; R = average of the ranks assigned to all items.

The calculated chi-square value with (N-1) degrees of freedom is as follows: (Siegel & Castellan, 1988)

$$\Psi^2 = k(N-1)W$$

where k = number of respondents ranking the items; N = number of items ranked.

The values of W of all respondents, client group, consultant group, and contractor group are 0.289, 0.281, 0.329 and 0.350, respectively. The levels of significance of all groups are 0.000 which are less than the allowable level of significance (5%), so the null hypothesis should be rejected. The Chi-square test was carried out because there were 12 items involved (more than seven items). The calculated Chi-square values of the client group, consultant group, and contractor group are 43.247, 43.406 and 69.318 which all of them are higher than the critical value of 19.675 from table (df = 11, $p < 0.005$) so the null hypothesis should be rejected as well. According to the results of the analysis, there is adequate evidence to conclude that the respondent's sets of rankings regarding the barriers to BIM implementation are dependent to each other with a significant degree of consensus within each group.

#### 4.1.3. Ranking agreement between the respondent groups

The Spearman's rank correlation coefficient was adopted to test the strength of a relationship amongst two sets of rankings [88]. The range of the Spearman's rank correlation coefficient ($r_s$) is from −1 to +1. The higher the positive/negative value of $r_s$, the stronger positive/negative linear correlation [3,80]. If $r_s = 0$, there is no linear correlation at all [80,86]. If $r_s$ is statistically significant at a predetermined significance level (e.g. 5%), the null hypothesis ($H_0$) which states that "no significant correlation between the two groups on the rankings" can be rejected. In other words, there is no significant disagreement between the two groups on the ranking exercise. The $r_s$ is calculated by the following equation:

$$r_s = 1 - \frac{6\sum d^2}{N(N^2 - 1)}$$

where d = difference in rank of the two groups for the same item; N = total number of responses regarding that item.

The $r_s$ for the barriers to BIM implementation in Hong Kong: (1) between the client group and consultant group, (2) between client group and contractor group, and (3) between consultant group and contractor group, are 0.678, 0.748 and 0.930. More so, the calculated significance levels are 0.015, 0.005 and 0.000, respectively which are lower than the allowable level of significance (5%). Therefore, the null hypothesis ($H_0$) should be rejected. In other words, there is a significant correlation between the client group and consultant group, between client group and contractor group, and between consultant group and contractor group on the rankings of the barriers to BIM implementation.

#### 4.1.4. Statistical differences among the respondents' groups

The Mann-Whitney U test was adopted to determine any divergences in the median values of the same item among two selected respondent groups [3,80]. The Mann-Whitney U test is used to determine any statistically significant differences or divergences in the median values of the same item between any two selected respondent groups [89]. The rule is that if the calculated p-value is less than the allowable significance level (e.g. 1%), the null hypothesis ($H_0$) which states that "*there are no significant differences in the median values of the same item between the two survey groups*" can be rejected [85,86].

The first pair is the client group versus the consultant group, the second pair is the client group versus the contractor group, and the third pair is the *consultant group versus contractor group*. For the first pair (client group versus consultant group), only one discriminating item is identified which is Item 3 – "insufficient interoperability of computer software" [30,38]. Interoperability is the ability to exchange information between different types of computer software to facilitate automation and presentation [13,42]. The description above of interoperability best describes "technological interoperability" which refers to the exchange of information between different software. With good interoperability of BIM, the client can make use of data to facilitate the schedule in the construction stage and extract the data from the BIM model to other software for the future use such as for the facility management phase and periodic maintenance. On the other hand, it enables BIM consultants to provide efficient BIM services and enable them in understanding related technical issues which they can tackle. Based on the analysis of the data, the BIM consultants identified the factor to be of less significant as a barrier to BIM adoption in Hong Kong.

Therefore, it is reasonable that the clients emphasize that insufficient interoperability of computer software may obstruct the implementation of BIM in Hong Kong. The details of the analysis are shown in Table 6. For the second pair (client group versus contractor group) and the third pair (consultant group versus contractor group), all the calculated p-values are larger than 0.01; and thus the null hypothesis ($H_0$) should not be rejected. Therefore, there is no discriminating item identified in the second pair and third pair.

### 4.2. Benefits of BIM implementation in Hong Kong

#### 4.2.1. Ranking results

The survey results of the ranking of the benefits of BIM implementation are presented in Table 7. For the 12 benefits identified, the mean (M) values range from the lowest mean score of M = 2.70 "Scope clarification" to the highest mean value of M = 4.45 "Better cost estimates and control." The three most significant benefits of BIM implementation include: better cost estimates and control (M = 4.45) [41,54,61]; better understanding of design (M = 4.39) [46,53], and reduce construction cost (M = 4.09) [22,60].

Most respondents agreed that the database and the auto-quantification function of BIM could enhance their accuracies and efficiencies for the cost valuation and audit. Furthermore, the majority of the survey participants opined that the application of n-dimension could make the participants easier to visualize and understand the design by using some essential functions like "rendering" and "walk-through" [13]. Moreover, they reckoned that the construction cost could be minimized because the BIM model can demonstrate the whole project procedures and address the potential risks before the commencement of the construction phase.

For the contractor group, these three most significant benefits are included in its top 3 items. However, the client and consultant groups considered that another item "better construction planning and monitoring" [67,68] is also essential, hence, the two respondents' groups considered in their top-three most significant factors. The findings are consistent with the fact that cost and time are always regarded as the prime concerns towards the clients, and the respondents perceive that BIM model facilitates effective site planning as well as reduce rework to save time and money. Therefore, the rankings of Item 6 and Item 8 are closely ranked in both the client group and consultant group.

#### 4.2.2. Ranking agreement within each respondent group

The Kendall's coefficient of concordance (W) was applied to measure the agreement of different respondents on their rankings regarding the benefits of BIM implementation based on mean values within a particular group. The values of W of all respondents, client group, consultant group, and contractor group are 0.382, 0.337, 0.422 and 0.486 respectively. The levels of significance of all groups are 0.000 which are less than the allowable level of significance (5%), so the null hypothesis ($H_0$) should be rejected. The Chi-square test was also employed because there are 12 items involved (more than seven items). The calculated Chi-square values of the client group, consultant group, and contractor group are 51.869, 55.690 and 96.275 which all of them are higher than the critical value of 19.675 from table so the null hypothesis should be rejected as well.

From the results of these two tests, there is adequate evidence to conclude that the respondent's sets of rankings regarding the benefits of BIM implementation are dependent to each other with a significant degree of consensus within each group. This concordance test enables the data and opinions collected from the questionnaire survey to be valid and consistent for further statistical analysis.

#### 4.2.3. Ranking agreement between the respondent groups

The Spearman's rank correlation coefficient was adopted to test the strength of a relationship amongst two sets of rankings [17]. The Spearman's rank correlation coefficient ($r_s$) of rankings of the benefits of BIM implementation: (1) between the client group and consultant group, (2) between client group and contractor group, and (3) between consultant group and contractor group, are 0.860, 0.867 and 0.818. The calculated significance levels are 0.000, 0.000 and 0.001, respectively which are lower than the allowable level of significance (5%). Therefore, the null hypothesis ($H_0$) should be rejected. In other words, there is a significant correlation between the client group and consultant group, between client group and contractor group, and between consultant group and contractor group, on the rankings of the benefits of BIM implementation.

#### 4.2.4. Statistical differences among the respondents' groups

The first groups of respondents for comparative analysis are: (1) the

**Table 6**

Results of Mann-Whitney U test for the barriers to BIM implementation (client group versus consultant group).

| Item | Barriers to BIM Implementation | Mean Rank | | Mann-Whitney U | Z-value | p-value | Conclusion to $H_0$ |
|---|---|---|---|---|---|---|---|
| | | Client Group | Consultant Group | | | | |
| 1 | High initial cost | 15.04 | 11.71 | 62.500 | −1.166 | 0.243 | Accept |
| 2 | Lack of expertise | 15.54 | 11.13 | 55.500 | −1.552 | 0.121 | Accept |
| 3 | Insufficient interoperability of computer software | 17.21 | 9.17 | 32.000 | −3.084 | 0.002 | **Reject** |
| 4 | Lack of training/courses | 14.64 | 12.17 | 68.000 | −0.862 | 0.389 | Accept |
| 5 | Cultural barrier (resistance to change) | 13.21 | 13.83 | 80.000 | −0.257 | 0.797 | Accept |
| 6 | Poor collaboration among project participants | 14.79 | 12.00 | 66.000 | −0.983 | 0.325 | Accept |
| 7 | Organizational structure that does not support BIM | 12.79 | 14.33 | 74.000 | −0.547 | 0.584 | Accept |
| 8 | Lack of subcontractors who can use BIM technology | 11.61 | 15.71 | 57.500 | −1.530 | 0.126 | Accept |
| 9 | Security risk | 12.64 | 14.50 | 72.000 | −0.671 | 0.502 | Accept |
| 10 | Lack of industry standards | 13.54 | 13.46 | 83.500 | −0.027 | 0.978 | Accept |
| 11 | Difficulties in measuring impacts of BIM | 14.29 | 12.58 | 73.000 | −0.646 | 0.518 | Accept |
| 12 | Shortage of BIM implementation data in construction phase | 13.29 | 13.75 | 81.000 | −0.164 | 0.869 | Accept |

**Table 7**
Benefits of BIM implementation in Hong Kong.

| Benefits of BIM Implementation | All Respondents | | Client Group | | Consultant Group | | Contractor Group | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Rank | Mean | Rank | Mean | Rank | Mean | Rank |
| Better cost estimates and control | 4.45 | 1 | 4.50 | 1 | 4.33 | 1 | 4.50 | 2 |
| Better understanding of design | 4.39 | 2 | 4.36 | 2 | 4.17 | 2 | 4.56 | 1 |
| Reduce construction cost | 4.09 | 3 | 3.93 | 5 | 3.92 | 4 | 4.33 | 3 |
| Better construction planning and monitoring | 4.07 | 4 | 4.14 | 3 | 4.17 | 2 | 3.94 | 5 |
| Improve project quality | 3.91 | 5 | 4.07 | 4 | 3.42 | 5 | 4.11 | 4 |
| Provide life cycle data | 3.39 | 6 | 3.29 | 9 | 3.17 | 6 | 3.61 | 6 |
| Improve safety performance | 3.36 | 7 | 3.43 | 7 | 3.08 | 8 | 3.50 | 8 |
| Speed up the design process | 3.27 | 8 | 3.36 | 8 | 2.75 | 11 | 3.56 | 7 |
| More efficient communications | 3.23 | 9 | 3.50 | 6 | 3.08 | 8 | 3.11 | 10 |
| Reduce project duration | 3.23 | 9 | 3.29 | 9 | 3.17 | 6 | 3.22 | 9 |
| Enhance organizational image | 2.98 | 11 | 2.86 | 11 | 3.00 | 10 | 3.06 | 11 |
| Scope clarification | 2.70 | 12 | 2.79 | 12 | 2.67 | 12 | 2.67 | 12 |

client group versus the consultant group, the second pair is (2) the client group versus the contractor group, and (3) the third pair is the consultant group versus contractor group. The rule is that if the calculated p-value is less than the allowable significance level (1%), the null hypothesis ($H_0$) which states that "*there are no significant differences in the median values of the same item between any two survey groups*" can be rejected [80].

For the first pair (client group versus consultant group) and the second pair (client group versus contractor group), all the calculated p-values are larger than 0.01; the null hypothesis should not be rejected. Therefore, there is no discriminating item identified in the first pair and second pair. For the third pair in Table 8 (consultant group versus contractor group), there is only one discriminating item identified which is Item 5 – "speed up the design process" [26,53]. The design process is a very engaging phase of project development as it involves several stakeholders [90–92] who contributes their ideas to the development of the building model. For the BIM consultants, they tend to spend more time collaborating with the various stakeholders [93] to produce the building models. This process may increase the workload required for the design stage. Therefore, the consultants believed using BIM early in the project will help speed up the design process. On the other hand, the contractors are usually not involved in the design stage.

## 5. Practical implications of research findings

The study examined the potential barriers to and perceived benefits of BIM implementation in the Hong Kong construction industry. The survey participants identified cultural barrier (resistant to change) [42], an organizational structure that does not support BIM [31], and insufficient interoperability of BIM software [34], as the three most significant barriers to BIM implementation in Hong Kong. A closer look at these barriers reveals that it falls within the purview of project stakeholders, firms, and BIM technology. Stakeholders resistant to change from the industry's traditional 2D approach to 3D is still prevalent [3], and a change in perspective is needed to improve the uptake of BIM in construction projects in Hong Kong both by the private property developers and the Hong Kong Housing Authority. Also, for constructions firms and property developers in Hong Kong, it is recommended for them to set up a specific BIM department to handle or facilitate BIM implementation in their construction projects in the long run.

Moreover, construction firms' senior management is encouraged to address the deficiency in their personnels' skill sets by sponsoring them to attend relevant BIM seminars, workshops or conferences to enhance their BIM capacity and knowledge development. Also, the establishment of in-house BIM department in firms and developers' organizations will reduce among other things the cost of outsourcing BIM services to freelance specialists and increase the technical competence of their staff. Interoperability or incompatibility of major BIM software is still a significant barrier in the global AEC industry. Hence, the study encourages more partnerships among these software vendors and construction firms. It is expected that the collaboration will help ensure a higher level of compatibility and reduce the incidence of loss of data during data migration between software. Also, full migration to cloud BIM by firms and developers alike could minimize the severity of this factor. The issue of interoperability is more hyped in this study by the client group and the consultantgroup of survey respondents.

Moreover, factors such as better cost estimates and control [61], better understanding of design [53], and reduction in construction cost [27], appear to be the three most significant benefits of implementation of BIM in Hong Kong. The three most beneficial factors can be regrouped into cost control related benefits and design benefits. Proper implementation of BIM in Hong Kong will ensure project cost are better

**Table 8**
Results of Mann-Whitney U test for the benefits of BIM (consultant group versus contractor group).

| Item | Benefits of BIM Implementation | Mean Rank | | Mann-Whitney U | Z-value | p-value | Conclusion to $H_0$ |
|---|---|---|---|---|---|---|---|
| | | Consultant Group | Contractor Group | | | | |
| 1 | Improve project quality | 12.50 | 17.50 | 72.000 | −1.590 | 0.112 | Accept |
| 2 | Better understanding of design | 13.08 | 17.11 | 79.000 | −1.377 | 0.169 | Accept |
| 3 | Provide life cycle data | 13.33 | 16.94 | 82.000 | −1.191 | 0.234 | Accept |
| 4 | Scope clarification | 15.33 | 15.61 | 106.000 | −0.091 | 0.927 | Accept |
| 5 | Speed up the design process | 10.63 | 18.75 | 49.500 | −2.683 | 0.007 | **Reject** |
| 6 | Reduce construction cost | 12.50 | 17.50 | 72.000 | −1.788 | 0.074 | Accept |
| 7 | Better cost estimates and control | 14.00 | 16.50 | 90.000 | −0.887 | 0.375 | Accept |
| 8 | Better construction planning and monitoring | 17.17 | 14.39 | 88.000 | −1.050 | 0.294 | Accept |
| 9 | More efficient communications | 15.38 | 15.58 | 106.500 | −0.068 | 0.946 | Accept |
| 10 | Reduce project duration | 16.08 | 15.11 | 101.000 | −0.326 | 0.744 | Accept |
| 11 | Improve safety performance | 13.42 | 16.89 | 83.000 | −1.190 | 0.234 | Accept |
| 12 | Enhance organizational image | 15.42 | 15.56 | 107.000 | −0.047 | 0.963 | Accept |

estimated as well as minimizes the incidence of under-budget or over-budget; this will help eradicate the prevalence of cost overruns in construction projects. Previous research studies [3,94] have revealed cost savings as one of the key benefits gained in deploying BIM in a project. However, Fazli [94] argued further that the gains made by the construction firms are consumed by the time, cost, and other resources needed to train up staff needed to use BIM effectively. The issue above according to Fazli [94] had deterred some firms and made them less interested in adopting BIM. Olawumi and Chan [95] recommended the establishment of a start-up funding scheme for construction firms, especially for smaller companies. Hence, clients who demand the use of BIM in their projects are most time in an advantageous position to benefits more from projects' cost savings that the construction firms involved; in the form of less cost to complete such projects which will free up funds for the client for other projects.

It is observed from the results of the Mann-Whitney U test for the barriers to and benefits of BIM implementation that only one item each among the group pairs showed a statistically significant difference. The findings are consistent with the nature and structure of the Hong Kong construction industry in which a significant portion of the market share is controlled by some leading developers who sometimes function as a client, consultant or contractor depending on the level of their involvement in the project. More so, as argued by Olatunji et al. [79] that a situation whereby construction stakeholders have practiced their profession in more than one of these organizational setups, it might influence their perceptions and leads to little or no difference in their opinions on a set of observed items.

Some BIM software has advanced to the 5D-BIM development phase [19], hence ensuring proper accounting and estimating of all project activities and processes from inception to completion. Furthermore, BIM software facilitates changes in one view to be observed in other views, and its intelligence at the object level has facilitated better understanding of project designs and drawings. This benefit is of great value to project stakeholders has it allows them to have a grasp of the design and allows the clients to appreciate the works of the project team in facilitating its use for their projects. It also facilitates the ease of producing 2D drawings for reference use on the project site, walk-through visualizations and, the use of augmented reality to detect errors on site and clash detection among others. Roberts et al. [96] highlighted issues such as property rights (such as virtual property [VP] & intellectual property [IP]) as a critical barrier to collaborative working among stakeholders as each construction organization works toward protecting their designs or company's data. Although the issue was not part of the barrier factors, it can be classified under the factor – "poor collaboration among project participants" as a causative factor. Essentially, several other factors can be deduced as causal factors influencing some of the factors (barriers and benefits) identified in this paper.

A recent Delphi survey conducted by Olawumi et al. [3] in eight countries which included the United States, the United Kingdom, Australia among others also reinforced the barrier factor "cultural barrier (resistance to change) as a key barrier to the implementation of BIM in the construction sector as the factor was ranked as first among other set of factors. More so, in the survey above [3], the lack of commitment by construction firms' top management also featured as a top-five ranked factor which is closely similar to barrier factor such as "organizational structure that does not support BIM" in this study. More so, another study by Olawumi and Chan [17] highlighted the benefit factors- "better construction planning and monitoring," "better understanding of design," and "improve project quality" as key benefits derivable by the construction industry when BIM is implemented. Li [97] affirmed that the use of BIM could help quantity surveyors to ensure better estimating, reducing overall project schedule, facilitating project coordination and collaboration, reducing life cycle project cost, and avoiding design errors and risks.

The Hong Kong Construction Industry Council (CIC) and the Hong Kong Institute of Building Information Modelling (HKIBIM) recently commissioned a consultancy team to develop a BIM industry standard for Hong Kong, which is a good step towards enhancing the local implementation and development of BIM. The BIM industry standard is expected to establish a process for adopting BIM in building, civil and other infrastructure development projects. Parts of the commissioned team's objective is to enable a client to specify, manage and assess BIM deliverables by architects, engineers, surveyors, and contractors. It will also ensure that project deliverables produced using the BIM processes to achieve an agreed level of quality. The principle for its development is the planning, implementation, management, and checking of the use of BIM on a project and to ensure the delivery of the BIM process meet the established targets.

## 6. Conclusions

The study assessed salient issues affecting the execution of BIM in Hong Kong and carried out a brief review of BIM implementation in the leading economies of the world such as the United States and the United Kingdom. Moreover, several factors were identified as major benefits of and barriers to BIM implementation in Hong Kong by a group of survey respondents from the consultant, contracting and client organizational in Hong Kong. More so, a comparative analysis of the perceptions of the three main respondents' groups was undertaken and analyzed, and the discussion of the findings presented.

The five most profound barriers are: cultural barrier (resistance to change), organizational structure that does not support BIM, insufficient interoperability of computer software, lack of industry standards, and difficulties in measuring impacts of BIM. Moreover, the five most important benefits include: better cost estimates and control, better understanding of design, reduce construction cost, better construction planning and monitoring, and improvement of project quality. The BIM consultants and contractors underscore the importance of BIM to speed up the design process. Also, there was a relatively good level of consensus among the respondents' groups on the identified barriers and benefits. More so, as highlighted in Section 5, some research studies corroborated the findings of this study as prevalent in other climes.

In most developed economies, the role of the government in the advocacy and implementation of innovative technology is highly integral to BIM's successful adoption in the AEC industry. Therefore, the study recommends for the local authorities to consider establishing a start-up funding for the construction companies to enable them to adopt BIM in their firms and projects. Especially for small-sized and median-sized firms, the financial support from the government can form a strong incentive for them to launch BIM in construction projects. Furthermore, some relevant bodies like HKIBIM and CIC should strengthen professional training activities such as BIM workshops, seminars, technical forums and induction of BIM experts to improve the BIM skills and knowledge of their members and staff. Moreover, these professional bodies can coordinate with other technical professionals to develop some useful and helpful software to facilitate the data interoperability between BIM and other software.

Section 5 discussed the practical implications of the research findings to knowledge and the industry. The findings revealed that most of the major barriers to BIM implementation relate to the project stakeholders and use of technology. Hence, a dynamic change in attitude, working, and policies of construction firms and the project team will mitigate the effect of some of these barriers on BIM implementation. More so, the significant benefits that the key construction project stakeholders can gain from BIM adoption is mostly related to the efficient delivery of project objectives regarding cost, time, and quality. The highlighted benefits can be enhanced and reaped when the current collaborative working environment in the construction industry is improved as well as addresses the issues of interoperability of computer software.

The Hong Kong CIC and HKIBIM are coordinating steps to develop a BIM standard for the whole Hong Kong construction industry which ameliorates the effect of the lack of uniform BIM standard within the industry. Implementing innovative technologies in the construction industry is a lengthy process. Therefore, the construction firms, government departments, and key stakeholders should lead the process of ensuring BIM uptake and implementation takes a continuous increase in the Hong Kong construction industry. For future research studies, case study investigations can be explored to supplement the contents and findings of the current research study including the benefits, barriers, and drivers for BIM execution in Hong Kong.

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## Appendix A. Supplementary data

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