Kanimaruthan, P., Kulatunga, U. and Thennakoon, T.M.P.N., 2024. Integrating 5D-BIM approach optimising quantity calculation efficiency in the Sri Lankan construction industry. In: Sandanayake, Y.G., Waidyasekara, K.G.A.S., Ranadewa, K.A.T.O. and Chandanie, H. (eds). *Proceedings of the 12th World Construction Symposium*, 9-10 August 2024, Sri Lanka. pp. 634-647. DOI: https://doi.org/10.31705/WCS.2024.50. Available from: https://ciobwcs.com/papers/

INTEGRATING 5D-BIM APPROACH OPTIMISING QUANTITY CALCULATION EFFICIENCY IN THE SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

Quantity calculation is a key component of the cost estimation process. Cost consultancy firms encounter various challenges such as higher time consumption, lower accuracy, higher expenditure for employees, and higher stress levels for estimators when conventional methods are practiced for quantity calculation. The drawbacks of quantity calculation with conventional methods can be effectively addressed through the adoption of 5D-Building Information Modelling (BIM) based quantity calculation. 5D-BIM is one of the dimensions of BIM which is beneficial in Quantity Surveying related aspects. Thus, this study aims to investigate the advancements of 5D-BIM that can be brought to the quantification approaches in the Sri Lankan context. Accordingly, a qualitatively based extensive literature synthesis has been conducted to review the concept of 5D BIM, ascertain the problems of conventional quantification methods, identify the key features of 5D BIM-based quantity calculation, and explore how the problems of conventional quantification approaches can be solved by the key features of 5D-Building Information Modelling (BIM) based quantity calculation. Following the qualitative approach, data were collected through eleven semi-structured expert interviews. Experts were selected through purposive sampling followed by snowball sampling. The data analysis was conducted through manual content analysis. Findings revealed context, features of 5D-BIM-based quantity calculation which solve the problems of conventional methods in the Sri Lankan context which includes high time consuming, lesser accuracy, minimal collaboration, inefficient for preliminary stage estimating and inefficient for cost planning with cross-reference to the findings in the literature review. In addition to the findings in the literature review respondents were suggested problems in conventional methods in Sri Lanka and how those problems can be addressed through key features of the 5D-BIM approach.

Keywords: *5D-Building Information Modelling (BIM); Conventional Quantity Calculation; Quantity Calculation; Quantity Surveyor (QS).*

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1. INTRODUCTION

Cost estimation is an important task for determining the cost of a construction project (Ismail et al., 2016). As the project complexity increases, the cost estimation consequently becomes more difficult and time-consuming (Bettemir, 2018). Quantity calculation is an inherent and prominent component of the cost estimation process (Varma et al., 2016). Requirements of investors in providing value for money and improving the efficiency and accuracy of cost estimates have become challenges in the construction industry (Babatunde et al., 2020). Despite the importance of cost estimation and quantity calculation, the efficiency of traditional estimating methods has been questioned, especially when dealing with the increased competition within the construction industry (Babatunde et al., 2020). Improper calculation of quantities is one of the critical factors that affect the cost performance of a construction project (Doloi, 2012; Fazeli et al., 2021). More importantly, cost performance can be affected due to inaccurate quantity calculations and inaccurate BOQ Human errors have had a negative impact on the conventional quantity take-off process in various instances. Additionally, even after the identified errors have been rectified, there is no guarantee of the reliability of calculated quantities (Monteiro & Martins, 2013).

"Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility and BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle" (National Institute of Building Sciences [NIBS], 2007, P.8). Moreover, BIM represents geometric and non-geometric details of building in a digital way and can be used for various purposes (NBIMS, 2010, as cited in Stanley & Thurnell, 2014).

5D BIM facilitates quantity calculation, modification, and extrication of data incorporated within the BIM model to become a prime source of information that could be used in Quantity Surveying practices (Stanley & Thurnell, 2014). In addition, many firms identified 5D BIM as a competitive approach to cost management of construction projects (Smith, 2016). 5D BIM confers the facility for Quantity Surveyors (QSs) to generate quantities directly from a properly updated BIM model through 5D BIM-based software. As the monotonous quantification task can be simplified through 5D BIM, it offers ample time for QSs to provide more focus on other project-related specific aspects including factorising risk and pricing (Autodesk, 2007, as cited in Mayouf et al., 2019).

5D BIM offers numerous advantages to the construction industry including increased understanding of the project through digital representation (Stanley & Thurnell, 2014; Usman et al., 2019), improvement in the accuracy of quantity calculation (Usman et al., 2019; Wahab & Wang, 2022), increased collaboration among the project team (Hasan & Rasheed, 2019), integration of time, cost, and other parameters in one model (Nawari & Ravindran, 2019), early detection of clashes and design errors, mitigation of risks associated with costing and scheduling and other related benefits (Hasan & Rasheed, 2019). Further, the Quantity Surveying practice can be shifted from spending significant time in quantity calculation to validating the generated quantities with the advent of 5D BIM (Sylvester & Dietrich, 2010).

Although 5D BIM can provide numerous advantages in terms of quantity calculation, there are some problems regarding the 5D BIM-based quantity calculation. For instance, cultural resistance, inadequate qualified staff, higher initial cost, inadequate protocol and criteria, inaccurate quantifications due to inadequate design details, problems due to interoperability, and other related limitations (Hasan & Rasheed, 2019; Smith, 2014). More importantly, bulk checking of quantities is required to ensure whether the generated quantities are correct (Harrison & Thurnell, 2015; Stanley & Thurnell, 2014). However, Stanley and Thurnell (2014) have stated that through effective collaboration between relevant stakeholders in BIM modelling, some existing problems related to 5D BIM could be overcome. In addition, Harrison and Thurnell (2015) argued that through continuous usage of 5D BIM and ensuring that required inputs are provided by designers to the model, benefits from 5D BIM can be enhanced.

Olatunji and Sher (2015) emphasised that with the advent of BIM for estimation purposes, there is a requirement for research regarding advances in BIM. This aspect promoted several studies on 5D BIM related to Quantity surveying practices. Therefore, this paper aims to provide a detailed investigation of 5D BIM-based quantity calculation in the Sri Lankan context. Following the aim of this study the objectives were set as overview of conventional Quantity calculation and its problems, identifying the key features of 5D-BIM-based quantity calculation and method of solving the problems of the conventional method. and identifying the problems related to conventional quantity calculation and methods of solving them using 5D-BIM features in the Sri Lankan context. First two objectives were addressed through literature synthesis and the third objective was addressed through the data collection section. Moreover, collected data were analysed using manual content analysis.

2. OVERVIEW OF CONVENTIONAL QUANTITY CALCULATION

Cost estimation is a cost forecasting process employed to ascertain the prospective cost of a construction project (Akcay et al., 2018; Kurasova et al., 2021; Washington State Department of Transportation, 2015). Elfaki et al. (2014) identified cost estimation as a prominent preliminary process of any construction project. An estimator primarily concentrates on estimating the cost of a construction project and provides a basic idea regarding the cost before the commencement of work (Varma et al., 2016). Estimation is a core aspect of the construction project; the accuracy of estimates ranging from early cost estimates to tendering stage estimates can influence the success of a construction project. Proper quantity calculation is of vital importance in the cost estimation process as inaccurate quantity calculation could result in erroneous cost estimates (Bettemir, 2018). Currently, quantity calculation is mostly done using 2D estimation software including Planswift, Timberline, and Onscreen Takeoff (Wahab & Wang, 2022). The authors further mentioned that manual taking-off based on hardcopy drawings also prevails in the industry.

2.1 PROBLEMS IN CONVENTIONAL QUANTIFICATION

As traditional-based quantity calculation relies on the human element, errors associated with the human element could result and more complicated structures could not be effectively quantified (Monteiro & Martins, 2013). Higher time consumption (Hasan & Rasheed, 2019; Mayouf et al., 2019; Shen & Issa, 2010; Smith, 2016), lesser accuracy (Hasan & Rasheed, 2019; Shen & Issa, 2010), and minimal collaboration (Hasan & Rasheed, 2019; Mayouf et al., 2019) are some of the major drawbacks associated with manual and 2D-software based quantity calculation methods. Similar to Hasan and Rasheed (2019) and Lee et al. (2005) expressed that traditional quantification entails a time-consuming quantification process since the detailed assessment of measurements is associated with this process. This aspect becomes more problematic on large-scale projects where a significant amount of drawing details needs to be handled, more importantly, when frequent design changes are experienced, inaccurate estimates could ultimately result (Royal Institution of Chartered Surveyors [RICS], 2014). In several circumstances, human errors can occur during manual take-off. Moreover, even after the correction of identified errors, assurance cannot be provided for the prepared estimate (Monteiro & Martins, 2013); nevertheless, 2D software takeoff is identified as one of the commonly used estimating methods in the present construction industry (Matejka & Vitasek, 2018).

In addition, manual or 2D software-based takeoff methods are inefficient for estimating purposes that are required during the preliminary stages of a project (Harrison & Thurnell, 2015; Stanley & Thurnell, 2014). During the design stage, as per the requirements of designers or clients, QS may be required to deliver cost advice on various design options. Moreover, the designers may require ensuring that a cost-effective design is maintained (Wahab & Wang, 2022). In addition, Wahab and Wang (2022) mentioned that through the conventional 2D-based quantity take-off methods, it is difficult to make an effective decision instantly. The reason behind this difficulty is that manual or 2D software-based takeoff methods require significantly more time to prepare takeoffs for various design options to enable comparison (Abanda et al., 2017).

Manual and 2D software-based takeoff methods are reported to be less appropriate for cost planning purposes (Harrison & Thurnell, 2015; Stanley & Thurnell, 2014). When considering 2D software-based quantification for cost planning, it would consume a considerable amount of time and may not be effective in managing the complexities of conducting comparative analysis within the designated time frame for the design development process (Smith, 2014). Table 1 summarises the problems of conventional quantification methods.

Table 1: Problems of conventional quantification methods

Problems	Authors
High time consuming	Wahab & Wang (2022); Lee et al. (2005); Smith (2016); Hasan & Rasheed (2019); Shen & Issa (2010); Mayouf et al. (2019)
Lesser accuracy	Wahab & Wang (2022); RICS (2014); Monteiro & Martins (2013); Hasan & Rasheed (2019); Shen & Issa (2010)
Minimal collaboration	Wahab & Wang (2022); Hasan & Rasheed (2019); Mayouf et al. (2019)
Inefficient for preliminary stage estimating	Abanda et al. (2017); Stanley & Thurnell (2014); Harrison & Thurnell (2015)
Inefficient for cost planning	Smith (2014); Stanley & Thurnell (2014); Harrison & Thurnell (2015)

3. BUILDING INFORMATION MODELLING (BIM)

According to Associated General Contractors of America (2005), BIM is the development and use of a computer software model to simulate the construction and operation of a facility.

With its potential and momentum, BIM began to receive more recognition within the construction sector (Mayouf et al., 2019). BIM provides an IT-enabled centralised approach where all disciplines can collaboratively work on a centralised model effectively (Bryde et al., 2013; Grilo & Jardim-Goncalves, 2010). Moreover, BIM as a modern paradigm has an adequate capacity for incorporation during the total life cycle of construction projects (Nagalingam et al., 2013). Various concerns associated with traditional processes in terms of the management of information could be resolved through the adoption of BIM (Smith, 2014). Different subsets of BIM are generally referred to in terms of dimensions (Ds) including 4D (time factor), 5D (cost aspect), 6D (facilities management), 7D (sustainability), and other subsequent dimensions in which each dimension is an outcome of the data/information layer incorporated within the BIM model (Eastman et al., 2010; Smith, 2014). Stanley and Thurnell (2014) mentioned that 5D BIM can be straightly used to price the construction works as model objects contain data related to specification and other relevant properties. 5D BIM encompasses objects and assemblies within the BIM model, which contains a cost dimension incorporated into it either through inserting cost data with the BIM model objects, or that can be linked with estimating software tools (Boon & Prigg, 2012). However, as per the current practice, 5D BIM is used outside the core of the BIM model through live linking with a third-party estimating tool (Stanley & Thurnell, 2014).

3.1 KEY FEATURES OF 5D-BIM-BASED QUANTITY CALCULATION AND METHOD OF SOLVING THE PROBLEMS OF CONVENTIONAL METHOD

According to Thurairajah and Goucher (2013), since BIM model objects contain geometrical properties and objects represent the elements of the building, automatic quantity extraction is enabled through BIM models. Through automation, the duplication work of manually quantifying what designers have already done can be simplified thereby a significant amount of time-saving could be achieved (Hannon, 2007). Further, automatic quantification reduces human error and improper drawing interpretation thereby increasing the accuracy of the estimate (Rundell, 2006). Similar to Hannon (2007) and Wahab and Wang (2022) added that 5D automation assists extensively in accurately quantifying complicated building elements.

3D Visualisation allows the users to obtain a proper understanding of the project design (Goldberg, 2007). 3D visualisation also simplifies the overall estimation process since it provides a better understanding of the orientation and integration of building elements (Aibinu & Venkatesh, 2014; Stanley & Thurnell, 2014; Usman et al., 2019).

The introduction of BIM has encouraged a collaborative work environment with a single central model where changes in design can be updated automatically and coordinated with the project team members (Hasan & Rasheed, 2019; Nawari & Ravindran, 2019). Further to (Nawari & Ravindran, 2019), BIM introduces an ideal way of interconnecting all relevant data into a centralised-shared model including geometrical, temporal, financial, and property management layers.

Incorporating design changes in the estimate is a tedious task in the conventional quantification method (Wahab & Wang, 2022). However, in the 5D-BIM-based method, design changes can be conveniently accommodated (Harrison & Thurnell, 2015; Kamardeen, 2010; Stanley & Thurnell, 2014). Moreover, during design changes, 5D-BIM could assist in rapidly comparing different design alternatives and assessing the consequences of design to the total cost (Lu et al., 2016; Vigneault et al., 2019). Accuracy of the estimate and time requirement can be maintained at a desirable level as design alterations are easily managed in 5D BIM-based quantity calculation (Wahab & Wang, 2022).

4. RESEARCH METHODOLOGY

The research approach refers to the systematic plans and procedures used to conduct research, encompassing the progression from broad hypotheses to specific techniques for collecting, analysing, and interpreting data (Ritchie et al., 2013). For this study, the qualitative research approach has been used because the qualitative research approach is adopted to represent the perceptions, experiences, beliefs, and viewpoints of a particular group of people and this approach is an ideal option for research regarding emerging conceptions investigations (Ritchie et al., 2013). Generalising research findings is not expected in most of the qualitative research (Dawson, 2007). This paper addressed the research problem "What are the advancements of 5D BIM-based quantity calculation that solve the problems of conventional quantity calculation methods in the Sri Lankan context?".

The study required gathering information regarding problems of conventional quantity calculation methods, advancements of 5D BIM-based quantification, and improvements to 5D BIM-based quantification through an in-depth inquiry. The flexibility to adjust the questions during the study was also required. Hence, semi-structured interviews have been selected for this research as a data collection technique. Accordingly, eleven interviews were conducted with experts in 5D BIM-based quantity calculation to explore the problems of conventional quantity calculation methods in the Sri Lankan context, key features of 5D- BIM-based quantity calculation which addresses the problems of conventional quantification approaches with cross-reference to the findings in the literature review.

Sampling is used to select appropriate samples from the established population (Taherdoost, 2016). This study required the notions of experts who have adequate experience in both conventional quantification and 5D BIM-based quantification. Therefore, purposive sampling is initially adopted to identify experts who fulfill the requirements. In addition, snowball sampling is adopted for the instances where it is difficult to identify the potential respondents from the defined population (Etikan & Bala, 2017). In the Sri Lankan context, 5D BIM adoption has occurred recently and it is difficult to identify the respondents who have adequate experience in both 5D BIM-based quantification and conventional quantification. Therefore, followed by purposive sampling, snowball sampling was also adopted to identify respondents for this study. Accordingly, as mentioned above the initial sample was limited to interviews of Eleven (11) respondents who were saturated after the ninth interview. Table 2 summarises the profile of the interviewees.

Table 2: Profiles of interviewees

Code	Designation	Number of projects involved with 5D-BIM-based quantity calculation	Industry Experience
R1	Quantity Surveyor	More than 50	5
R2	Senior Consultant Quantity Surveyor	More than 30	11
R3	Quantity Surveyor	More than 30	4
R4	Senior Quantity Surveyor, BIM leader for QS division	More than 30	9
R5	General manager-Estimation	20	16

Code	Designation	Number of projects involved with 5D-BIM-based quantity calculation	Industry Experience
R6	Quantity Surveyor	12	5
R7	Quantity Surveyor	10	4
R8	Director, Senior Quantity Surveyor	8	17
R9	Senior Quantity Surveyor	8	15
R10	Director, Senior Quantity Surveyor	6	30
R11	Director, Senior Quantity Surveyor	5	18

5. RESEARCH FINDINGS

Based on the generic factors that are identified in the literature review related to problems in conventional quantification key features of 5D-BIM-based quantity calculation for solving these problems were analysed according to the opinions of the experts. The collected data were analysed through manual content analysis. Consequently, findings through the conducted expert interviews have been discussed as follows.

5.1 PROBLEMS RELATED TO CONVENTIONAL QUANTITY CALCULATION AND METHODS OF SOLVING

Problems regarding conventional quantity calculation methods in the Sri Lankan context were gathered through expert interviews. Accordingly, Table 3 indicates the responses of experts regarding problems of the conventional quantity calculation methods. Six additional problems were identified beyond those identified in the literature review.

Table 3: Problems related to conventional quantity calculation methods

Factors	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
Higher time consumption	√	√	√	√	√	√	√	√	√	√	√
Lower accuracy		√		√	√	√	√	√	√		√
Minimal collaboration	√	√	√	√	√	√	√	√	√	√	√
Inefficient option for preliminary stage estimating	√		√		√		√	√	√		
Inefficient option for cost planning	√		√		√		√	√	√		
Difficulties in understanding the drawing	√	√	√	√	√	√	√	√	√	√	√
Hard to trace back				√			√				√
High cost for estimators	√			√							
Mismatches among drawings		√									
Hard to compile the work of different employees				√							
QSs feel discomfort							√				

5.1.1 Higher Time Consumption

All the respondents criticised that higher time consumption is a prime problem associated with conventional quantification approaches. On this issue, R2 elaborated that conventional quantification is a tedious task and QSs may be required to refer to different parts of the drawings to measure a single item. By agreeing with R1, R7, and R8, R2 mentioned that through 5D-BIM-based quantity calculation, manual works in quantification can be **automated** thereby significant time saving can be achieved. R2 mentioned, *"Various details are integrated into one place. Therefore, together with the automation, information integration assists in achieving a higher level of time-saving"*. R1 added that this **information integration** simplifies the quantity-checking process since it is not required to refer to various drawings to check one element. R7 stated that in most instances, design changes are initiated during the quantity calculation process. R7 further stated that since 5D BIM facilitates accommodating **design changes conveniently**, the total time required for the quantification process is minimised. R1 and R4 commented that the 5D BIM-based method expedites the communication in the quantification process through **increased collaboration**.

5.1.2 Difficulties in Understanding the Drawing

According to the explanation provided by R5, in the 5D-BIM-based quantity calculation method, building elements can be virtually visualised in 3D. Therefore, unlike the conventional method, QS can quickly obtain a proper understanding of what is going to be quantified. It assists in doing the quantity calculation properly.

5.1.3 Lower Accuracy

Eight respondents contended that the **accuracy of the conventional quantification is lower**. R11 mentioned, *"possibility of making errors is quite higher in terms of missing quantities and during quantity calculation. Therefore, the collective accuracy of the quantity estimate is lower"*. This reasoning is aligned with the explanation presented by R4. Moreover, by agreeing with R3, R1 brought a different perspective for the reasoning on lower accuracy. R1 proposed, *"due to the intensive involvement of human element, human-related errors can occur in this process thereby accuracy is lower".* Conversely, R10 believes that the accuracy of the conventional method is reasonable. However, deviating from the above arguments, both R2 and R9 argued that the accuracy of conventional quantity calculation depends on the person who is doing it. R2 stated, *"Knowledge and understanding of the person especially on structural element influences on the accuracy"*. Moreover, R9 added that the interest of the person also affects the accuracy of the output.

R1 stated that 5D BIM **automation** significantly replaces the involvement of the human element in quantity calculation. Therefore, human-related errors are minimised, and accuracy is improved. R8 elaborated, *"For example, when you are measuring an area of a curvy element in the conventional method, you may be required to draw a polyline. When drawing the element, you may make mistakes. Similarly, there are various mistakes. However, the 5D BIM-based method uses advanced calculation algorithms to calculate them with 100% accuracy"*.

5.1.4 Minimal Collaboration

R9 added that the interest of the person also affects the accuracy of the output. All the respondents mentioned that the **collaboration level is lower** among project stakeholders in the conventional project delivery method. According to R1 and R4, minimal collaboration and its consequential adverse impacts are there with the conventional method. Decreased productivity, wastage of resources, communication deficiencies, decreased knowledge sharing and thereby decreased value addition to the project are some of the consequences of minimal collaboration. However, the 5D-BIM-based quantity calculation method minimises those consequences through **increased collaboration**.

5.1.5 Inefficient Option for Preliminary Stage Estimating and Cost Planning

Five respondents expressed that the conventional method is reasonable for the preliminary stage estimating. R2 mentioned that BIM models become more detailed at the design stage. However, six respondents argued that **the conventional method is inefficient for the preliminary stage estimating**. R1 described, *"Basically conventional method is inefficient for the preliminary stage estimating since it involves various manual quantification works. Moreover, the conventional method becomes more inefficient especially when the scale of project and complexity of the project is higher".* This argument is aligned with R3, R7, R8 and R9. According to R7 and R8, **all the six key features** identified above collectively help to improve the preliminary stage estimating. A similar trend of responses was received regarding the concerns associated with conventional cost-planning methods.

5.1.6 Hard to Trace Back

Three respondents stated that **tracing back quantities is a difficult** task in the conventional quantification method. R4 stated, *"When you need to check any quantities that are produced in the conventional method, of course, you can do that. But it is very difficult for you to identify how the quantities have been derived".* By agreeing with R4 and R7, R11 highlighted that the tracing back feature of the 5D BIM-based method including tracing quantity breakdown and tracing model demarcation helps to reduce the difficulties associated with checking the quantities.

5.1.7 High Cost for Estimators

R1 and R4 identified that the **cost for the estimators is higher** in the conventional method. R1 elaborated that in the conventional method, payment for estimators is provided based on the deployed man hours. R1 stated that 5D BIM **automation** significantly reduces the manual work of the estimators. Further to R1, the time requirement for quantity calculation is reduced thereby cost for the estimators can be reduced. Moreover, it should be noted that this cost reduction can be obtained when a project is large or complex.

5.1.8 Mismatches among Drawings

R2 stated that **mismatches among drawings** are also a drawback of the conventional method. R2 mentioned *"During the conventional method of quantity calculation, you will receive different types of drawings and design information such as plans, elevations, sections and specifications, etc. Everything will be in different places. Sometimes the information in one place does not match with the same information that you see in another place".* This aspect could cause problems in quantity calculation. R2 mentioned that **increased collaboration** in BIM helps to reduce the discrepancies between drawings. R2 further elaborated, *"in the conventional method, for example, you will find differences* *between Architectural drawings and structural drawings. This type of problem can be controlled through increased collaboration".*

5.1.9 Hard to Compile the Work of Different Employees

R4 asserted that in conventional quantification methods, quantification works of large projects are distributed among numerous estimators. Therefore, it is **difficult to compile the estimates of different estimators** since they may use different procedures, estimating techniques, tools, and formats. R4 opined that **automation** reduces the number of estimators working on one project and provides output in the same format. Further to R4, subsequently, difficulties in compiling the works are minimised.

5.1.10 QSs Feel Discomfort

R7 stated that compared to the conventional method, QSs' work is simplified in a 5D BIM-based method through **automation, virtual visualisation,** and **convenient accommodation of design changes**.

6. DISCUSSION

Respondents mentioned that the 'automation' and 'convenient accommodation of design change' features of the 5D BIM-based method reduce the time required for quantity calculation. This is consistent with the literature findings by Hannon (2007) and Wahab and Wang (2022) respectively. Further, respondents highlighted that 'information integration' also together with 'automation' facilitates the time reduction. According to Rundell (2006), 'automation' results in increased accuracy of quantity calculation. This aspect is aligned with the data collection findings. One respondent added that 'collaboration' enhances the accuracy of output as design changes can be effectively communicated to the estimator. In addition, respondents argued that the 'increased collaboration' of the 5D-BIM-based method assists in controlling the adverse consequences of minimal collaboration which is a drawback of the conventional method. Moreover, as per the collected data, 'virtual visualisation' reduces the difficulties in understanding the drawings. This is consistent with the literature finding by Goldberg (2007). Fewer research studies are focusing on what key features of 5D BIM help to improve preliminary stage estimating and cost planning. When analysing the responses it can be understood that 'automatic quantity extraction', 'tracing back of quantities', 'virtual visualisation', 'convenient accommodation of design changes', 'information integration', and 'increased collaboration' collectively assists in improving both the preliminary stage estimating and cost planning. The above-discussed problems were primarily identified from the literature as the main problems of the conventional method. The following problems were identified during the data collection process beyond the literature findings. Key features for the problems that were identified during the data collection are discussed below. The 'Tracing back' feature assists in checking the quantities easily. For large-scale or complex projects, 'automation' helps to reduce the expenditure for the estimators. Further, 'automation' controls the difficulties associated with compiling the works of different estimators who are working on a particular project under the conventional method. 'Increased collaboration' reduces the discrepancies between drawings. Moreover, 'automation', 'virtual visualisation', and 'convenient accommodation of design changes' collectively reduce the discomfort level of estimators.

Figure 1 summarises the collected data. On the left-hand side of the diagram, it illustrates the problems related to conventional quantity calculation methods. On the right-hand side of the diagram, it illustrates the 5D-BIM features that address those problems.

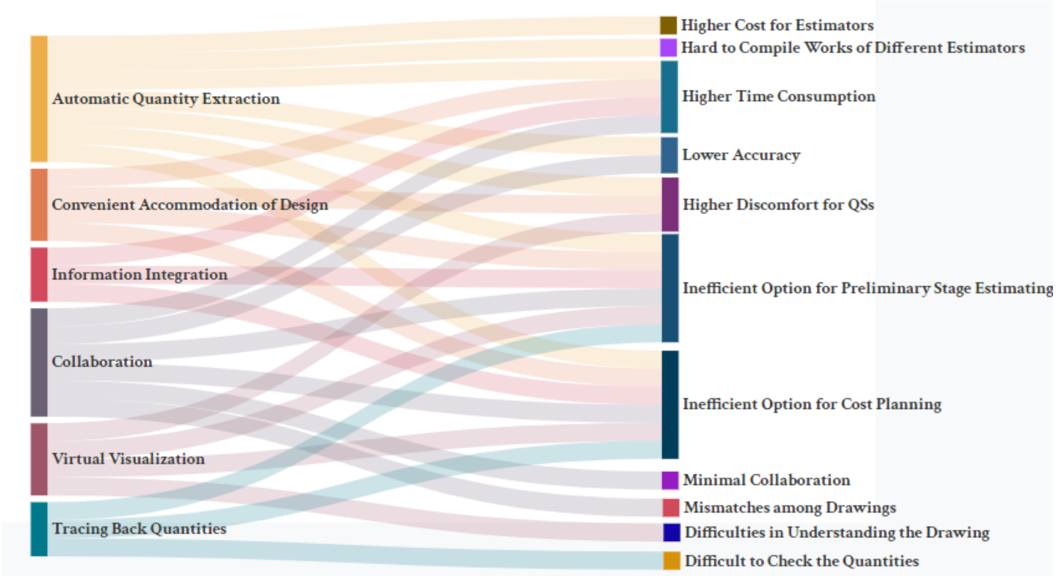

Figure 1: Problems related to conventional quantity calculation and solving 5D-BIM features

7. CONCLUSIONS

Numerous problems are associated with conventional quantity calculation methods. Higher time consumption and lower accuracy are the major drawbacks of conventional methods. Moreover, conventional methods are inefficient in multi-rate methods of preliminary estimating. Further, conventional methods are unproductive for preliminary estimating and cost planning when the project is larger in scope and higher in complexity. Similarly, conventional methods become less suitable for cost planning during the later stages of design development due to the availability of increased design details. From the perspective of the Quantity Surveying profession, 5D BIM is the prominent dimension of BIM technology. 5D BIM-based

quantity calculation entails numerous key features including ‘automatic quantity extraction’, ‘3D-visualisation’, ‘convenient accommodation of design changes’, ‘information integration’, ‘tracing back quantities, and ‘collaboration’. These key features are the pivotal factors that enable the potential of the 5D BIM in quantity calculation. Accordingly, this study assesses how the deficiencies of conventional quantification methods can be overcome through the incorporation of 5D BIM.

This study is limited to the Sri Lankan context, especially with the available 5D BIM-based quantification software used in the Sri Lankan construction industry. Future research should be focused on the “detailed comparison between 5D BIM-based cost estimation and conventional cost estimation can be done in the Sri Lankan context to ascertain whether there are any deviations from the outcomes of this research”. Moreover, the A framework can be developed to implement BIM in the Sri Lankan context in such a way that 5D BIM-based applications are effectively enabled as a future study.

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