IMPROVEMENT OF COST PERFORMANCE BASED ON BIM QUANTITY TAKE-OFF HOSPITAL STRUCTURE WORK

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Abstract. Indonesia's population is ranked 4th in the world after India and the United States, as well as the global Covid-19 pandemic, Indonesia is also recorded with the most cases of infections and deaths due to Covid-19 in ASEAN, therefore Hospitals in Indonesia has not been able to represent the need for beds and health services. Therefore, the hospital building construction project has become a driven demand for the fulfillment of health services for the Indonesian population. Estimation is one of the causes of the cost overrun. Implementation of Building Information Modeling Quantity take-off (BIM QTO) in hospital structural work can be done if the cost breakdown is \( \leq 24\% \). Statistical analysis by using the Relative Importance Index (RII) has a result in 10 rankings of factors that influence the implementation of BIM QTO, namely drawing, completeness Bill of Quantity (BoQ), TOR & specifications, cost reduction, preparation of activities in the work breakdown structure, cost breakdown, 3D modeling details, Data Interoperability, Quantity Take Off, Subcont & Supplier pricing, and cost database. Study cases with the implementation of BIM QTO on hospital building structures work cost efficiency up to 6.18%.

Keywords: Hospital, Structure, BIM Quantity Take-Off, Cost Efficient.
1. Introduction

The use of Hospital classified by two-term as public health building and/or infrastructure which contribute to Global Competitiveness Index [1]. Based on the Global Competitiveness Index (2017-2018), the vital role of the hospital indicated by the sector's contribution to the four pillars that form the basis of a country's factor-driven competitiveness: 1) institution, 2) infrastructure, 3) macroeconomic environmental and 4) health and primary educational [2]. Although an ideal governance structure should improve production efficiency and, at the same time, economize on the relevant transaction costs, different governance mechanisms often present different trade-offs between benefits and costs [3]. The need for a hospital in Indonesia has indicated by 1.16 beds per 1.000 people ratio less than ASEAN Countries 2.5-bed per 1.000 people [4]. The number of hospitals in Indonesia growth in 2015 grew by 7.98%, in 2016 it grew by 3.40% and in 2017 grew by 11.57% [5]. It means the public health expenditure has been increased to reach the rate of hospital beds per 1.000 people ratio.

In Indonesia, the hospital category has classified by 4 types based on facility and capability services there are types A, B, C, D, Pratama, and Non-Class. There are 63 units type A, 417 units type B, 1,453 units type C, 774 units type D, 27 units type D, and 74 units that even yet classified, that recorded at the end of 2019. In this research, the object of a hospital by using category hospital type C. The percentage of the hospital category in Indonesia has shown in Figure 1.

The percentage of the cost of structural works for residential buildings for the lower middle class is 37% of the total construction cost [6]. Traditional quantity take-off takes time, low accuracy, and create a miscalculation, automatic take-off using BIM base Quantity take-off is a solution to help prepare cost estimation [7]. Current research is expected to be oriented towards innovation and efficiency because with the demands of the advancement of times and science, it is necessary to raise new ideas or solutions in construction This research is the first to do regarding BIM Based Quantity Take-Off performance improvement on hospital building structural works.

2. Problem Statement

Cost overrun can be defined as when the project objectives are not achieved within the estimated budget [8]. Cost overrun happens when the cost incurred in the construction projects phase is more than the budget stated at the beginning of the project, causing a significant loss to the contractors [9]. The use of BIM quantity take-off has several challenges and obstacles [10]:
1. estimator's knowledge and understanding of BIM are inadequate.
2. Barriers to implementing data exchange between various applications such as BIM Authoring Tools and other estimation programs.
3. The limitation of maintaining the relationship between cost data and building elements is modeled in three-dimensional (3D) objects [10]. In addition to the three issues, the problem above is another difficulty, namely the difficulty of relying on volume data that is automatically retrieved from BIM, because the BIM drawn by the architect does not have sufficient properties.

Traditional computations take more time while computations extracted from BIM have the disadvantage of lacking properties to accurately estimate construction costs. Architects and estimators question who should be responsible for validating that the BIM-created during the design phase contains sufficient and sufficient information for cost estimation [11]. In response to this issue, the Royal Institution of Chartered Surveyors (RICS), the Association of Quantity Surveyors in the UK, established BIM guidelines aimed at professional estimators and established a suitable procedure for validation (RICS 2015). The guidelines include a process for confirming whether a suitable volume for the measurement rule can be obtained from BIM when examining the volume produced by BIM in the design stage [12] suggested modeling and measuring building elements to extract a volume suitable for BIM measurement rules. There are, however, constraints invalidating the measured quantities of BIM because of different quantities depending on the details of the BIM model components. Researchers have mentioned that the differences in the extraction quantity are due to the modeling and detail composition of the objects [13] (Monteiro & Poças Martins, 2013), and concern that variations in the amounts extracted from BIM could affect the accuracy of estimating construction costs (BoQ). From these problems it can be stated that this research is the first to be conducted regarding the increase in cost performance based on BIM Quantity Take-Off on hospital building structures. Poor knowledge about the benefits of BIM, resistance to change, poor training, and education all these are important barriers facing BIM use [14].

One of the key benefits of BIM is the accurate geometrical representation of building within an integrated information environment [15]. This is important according to what Rezakhani [16] says that due to the unique properties of construction operations, many risk factors are involved in the construction project. BIM also improves communication between the different project parties [17]. On the other hand, the cost of the initial investment for the application of the BIM is high, as it requires huge funds to buy the software and hardware required by certain specifications in addition to the cost of training and the wages of specialists, all of these barriers to the application of BIM. After the completion of the project, the BIM model is delivered by the client to the facility management team who are responsible for the maintenance and operation of the building [19]. Although the client considered the owner of the model belongs to him as he pays the price to the designers and parties responsible for producing the final model at the end of the project, but the researchers and specialists indicated to the unsafety the designers and parties involved in the production of the final model suffered in terms of ownership of their inputs.

3. Methodology Research

The study was conducted to analyze understanding and examine the effect of the application of BIM-based on Quantity Take-off on the work of the hospital building structure. The research begins with the formulation of the problem and the research title which is supported by a literature review. Libraries are collected following the topic of writing, for this writing, the appropriate libraries are topics regarding Building Information Modeling, Quantity Take-Off, Hospital Building structures, and articles on the application of the Relative Importance Index (RII) statistical tool.

To answer the Research Question (RQ2), which is to find the most influential factors for the implementation of BIM-based on Quantity take-off, the RII tool is used. Meanwhile, to answer the Research Question (RQ3) used a case study on hospital building structure work. The study was conducted to analyze understanding and examine the effect of the application of BIM-based on Quantity Take-off on the work of the hospital building structure. The
research begins with the formulation of the problem and the research title which is supported by a literature review. Libraries are collected following the topic of writing, for writing This appropriate library is the topic topics regarding Building Information Modeling, Quantity Take-Off, Hospital Building structures, and Articles on the application of the Relative Importance Index (RII) statistical tool.

3.1. Data Analysis

The data obtained by the researcher will be described and analyzed based on the accumulation of various dimensions and indicators. Research data obtained from the results of the distribution of questionnaires to the parties involved or have been involved in the work of Structures in High-rise Residential Buildings. The results of the processed statistics will get the factors that influence the application of BIM Based Quantity Take Off in high-rise residential work where the results will be displayed in tabular form, fishbone diagrams. The answer to the hypothesis, "Does BIM Based Quantity Take Off have an influence on the work of high-rise residential structures to improve project cost performance" and the results of the case study will also be discussed in this chapter which will then be the conclusion of this study analysis is carried out by analyzing the material by selecting and classifying its type and location in the 3D model. The location of the installation of the material greatly determines the calculation method so that this process is important to produce accurate calculation data. Figure 2 shows the quantity take-off process.

![Figure 2. Quantity Take-Off Process](image)

Relative importance index analysis allows identifying most of the important criteria based on participants' replies and it is also an appropriate tool to prioritize indicators rated on Likert type scales [20]. The contribution of each of the factors to overall delays was examined and the ranking of the attributes in terms of their criticality as perceived by the respondents was done by use of the Relative Importance Index (RII) which was computed using equation [21].

This analysis method will be done by using the data acquired from questionnaires which would produce the influential factors. RII will rank those factors based on their influence obtained from the scores given by the respondents in the questionnaires. The RII operation will be done by using Microsoft Excel, while the result of RII will undergo a validity test, reliability test, along with H1 and H0 hypothesis tests Relative Importance Index (RII) is a method of analyzing the most influential factors in the object of research. This analysis method is also processed by statistical calculations with the results of the questionnaire as input which will later be processed into influencing factors. RII determines the most influential factors with a ranking system based on the weight of the scores given from respondents after filling out
the questionnaire. In previous research, the use of the RII method was used to determine the influencing factors in research, through calculations with the following equation:

\[
\text{RII} = \frac{\sum W}{(A \times N)} \quad \text{(3.1)}
\]

Which is:
- RII = Relative Importance Index
- W = Weight (Weights ranging from 1 to 5)
- A = Highest Weight (In this research is 6)
- N = Total respondent

3.2. Determining The Number Of Samples (Respondents)

The questionnaire was composed of doing a literature study. The questionnaire contains a variable, main factor, and subfactor as its components. The next step would involve compiling the result of the literature study as questions that would be submitted to the respondents.

This study took samples of state-owned and private contractors working on hospital building projects in Indonesia, taking into account that the nature and objectives of the study were not affected by the research location. There are 3 (three) target respondents aimed at this study, namely: estimator, site manager, project manager. The sample used in this study were 39 respondents.

3.3. Pilot Survey

The initial stage for testing each questionnaire item so that it is understood by the respondent is a pilot survey. The number of survey pilots must represent the characteristics of the respondents. This research was conducted by a pilot survey of 3 (three) role model practitioners, namely site engineering/project planning, site manager, and project manager.

3.4. Determining the H1 and H0 hypothesis

A hypothesis is a supposition of the study result. The hypothesis has a temporary nature until it is proven to utilize a scientific study. The hypothesis itself must be constructed with a positive sentence without any doubts or suggestions.

For researchers to find factors that will influence the application of BIM Based Quantity Take Off in high-rise residential structure work, researchers used the statistical analysis method Relative Importance Index (RII). This analysis method is processed by statistical calculation of the results of the questionnaire as input which will later be processed into influential factors. The RII method determines the most influential factor with the ranking system based on the weighting of the value given by the respondent after completing the questionnaire. RII is operated using Microsoft Excel 2013 application program, while the results of the RII analysis will be carried out several tests such as validity, reliability, and H1 and H0 hypothesis testing. The following are the stages and results of RII statistical analysis.

3.5. Validity, Reliability, and Hypothesis Test

After obtaining the results of the questionnaire that had been recapitulated in the previous stage, 3 (three) testing of the respondent's data was carried out, namely testing the validity, reliability, and hypothesis testing. The test is carried out so that the quality results obtained are based on the testing technique criteria. The following is a test that must be done: Validity Test, Reliability Test, Hypothesis Test.
4. Implementation and Result

4.1. Collecting Data

41 questionnaire packages were successfully filled in and 13 that did not return. For more details, see Figure 3 below:

![Figure 3. Percentage of Numbers of Questionnaire](image)

4.2. Respondent Data

There are 3 (three) target respondents who are addressed in this study, namely the contractor, especially those who act as Site Engineering, Site Manager, and Project Manager. The purpose of determining the target respondents is so that the results of the questionnaire are more optimal because they are filled out by professional experts in their fields.

![Figure 4. Percentage of Respondent's Position](image)

The highest percentage of respondents' experience in this study was 5 < 10 years as much as 48.72%. Followed by the second-highest percentage of respondents 'experience, namely > 10 years of 38.46% and the lowest percentage of respondents' experience in this study, namely < 5 years of 12.82%.

![Fig. 5. Percentage of Type Of Project Respondent's Project](image)
Figure 5 shows that the highest percentage of implementation for a typical building in this study is a hospital building at 46%. The next highest percentage was for the implementation of bank building projects at 20% and commercial projects at 31%. The lowest percentage of project implementation is obtained in a typical hotel building, namely 3%.

4.3. Result Of The Most Influential Factors

The data tabulation of the questionnaire results has been obtained as can be seen in Appendix Table 1. Meanwhile, the results of the RII analysis can be seen in Table 2. The next step is to analyze the factors that most influence the object of research using the Relative Importance Index (RII) method. Relative Importance Index analysis allows identifying most of the importance based on participants’ replies and is also an appropriate tool to prioritize indicators rated on Likert type scales [22].

The results of the RII analysis are then compiled into a recapitulation which is presented in the form of sub-factor rankings, 10 most influential sub-factors, the most influential main factor rankings, and the most influential variable rankings. The results of the recapitulation of statistical analysis using the RII method, more details can be seen in the discussion below:

| Rank | Sub Factors                          | Value Index RII |
|------|-------------------------------------|-----------------|
| 1    | Drawing                             | 0.9951          |
| 2    | Bill of Quantity (BoQ)              | 0.9902          |
| 3    | TOR & Specification                 | 0.9854          |
| 4    | Cost reduction                      | 0.9805          |
| 5    | BIM QTO Modeling                    | 0.9756          |
| 6    | Individual Selection of Model       | 0.9707          |
| 7    | Quantity Take-Off                   | 0.9659          |
| 8    | Calculation Process                 | 0.9610          |
| 9    | Cost Database                       | 0.9561          |
| 10   | Operator Education                  | 0.9512          |
### Table 2. The Most Influential Main Factor

| Rank | Main Factor                  |
|------|------------------------------|
| 1    | DED                          |
| 2    | BIM QTO Process              |
| 3    | Operator BIM                 |
| 4    | Hardware & Software          |
| 5    | Reducing Volume              |
| 6    | Planning                     |
| 7    | Structural Work              |
| 8    | Supporting Factor            |

### Table 3. Variable X and Y

| Variable | Named                          |
|----------|--------------------------------|
| Y        | BIM Based Quantity Take-Off    |
|          | Hospital Work Structural       |

#### 4.4. Hypothesis Testing and Result

At this stage, the calculation of the correlation between variables X and Y is carried out.

### Table 3. Correlation X to Y

| X Y | Statistic Symbol |
|-----|------------------|
| N   | 39               |
| ΣX  | 3038             |
| ΣY  | 5168             |
| ΣX² | 225606           |
| ΣY² | 652142           |
| ΣX.Y| 383312           |
| r (X Y) | 0.6270 |

Source: Prepared by RII

\[
\begin{align*}
    r &= \frac{\frac{n}{\Sigma(x - \bar{x})(y - \bar{y})}}{\sqrt{\frac{\Sigma x^2 - (\Sigma x)^2}{n\Sigma y^2 - (\Sigma y)^2}}} \\
    &= \frac{41(383312) - (3038)(5168)}{\sqrt{(41(225606) - (3038)^2)(41(652142) - (5168)^2)}} \\
    &= 0.627016
\end{align*}
\]
Known as:
r = correlation \( r_{xy} \) = 0.6270
k = free = 1
n = number of respondents = 39
result value of \( r_{xy} \) = 0.627, then nilai \( F_{\text{calculation}} \) if \( f=1 \) and \( n=41 \) as follows:

\[
F_{\text{hitung}} = \frac{(r^2 \kappa)}{(1-r^2)} = \frac{\frac{0.627^2}{2}}{1-0.627^2(41-1-1)} = 25,26535 \quad \ldots \ldots (2)
\]

The results of the calculation of \( F_{\text{count}} > F_{\text{table}} \) or 710.22 > 4.11 then \( H_1 \) is accepted and \( H_0 \) is this means that "There is a significant relationship between the implementation of BIM-based on Quantity Take-Off on Hospital Building Structures Work".

4.5. Study Case Analysis

This discussion describes the process of implementing BIM based on Quantity Take-Off in Hospital Building Structures. Building Information Modeling (BIM) is a system, management, method, or sequence of execution of a project that is applied based on relevant information from all aspects of the building being managed and then projected into a 3-dimensional model [17].

The data and information obtained from the research results are arranged in several sub-chapters. The project data analysis sub-chapter explains the project data which is the object of the case study, which is detailed with job descriptions, work volume, price, and material specifications. The results of the calculation will be compared with previous studies with a chance of a decrease/difference in the value of between 24% (Arcadis 2019, Indonesia).

Reviewing at the beginning of the project process manual take-off activities are done by reading scaled drawings and until early 1980, it was still the main method for carrying out quantity take-offs [23]. In the preparation stage of the BIM Based QTO, the scope of structural work for the project is defined, which is then described in two forms, namely: Work Breakdown Structure (WBS) and Cost Breakdown Structure (CBS). In this study, the simulation of the implementation of BIM 5D-Based QTO is limited to concrete structure work items, which are jobs major in building structures in general. Thus, the quantity of taking off on the steel roof structure is not carried out. Before estimators make a cost quote or start a project, they need to know the type and amount of material they will need to complete it [24].

Based on project data, such as RAB or Bill of Quantity and Work drawings, a WBS of Structural Work (Concrete) was prepared for the Manahan Stadium Renovation Project in Surakarta. Figure 4.31 shows the WBS diagram that has been compiled for this study. Furthermore, the WBS is broken down back into CBS, based on the breakdown of the costs of the various components in each work item. This CBS will be used as a guide for what work items should be volume-extracted using the BIM 5D-Based QTO. The CBS Structural Work (Concrete) Project related Stadium is shown in Figure 4.32. (Arcadis 2019 Indonesia). A complete and detailed 3D BIM model will facilitate the processing of quantity take-off. [25].

Quality usually can be overcome with the application of the suitable technology and equipment, while the aspect of work safety can be handle with the proper implementation of safety management program especially in the field [26]. Implementation of BIM 5D-Based Quantity Take Off. In this study, the implementation of BIM 5D-Based QTO was carried out with the help of the Cubicost TAS C-II and Cubicost TRB 2020 software. Cubicost TAS (or Takeoff for Architecture and Structure) was used to extract concrete and formwork volumes on stadium project structure work in the study. this. While the Cubicost TRB (or Takeoff for Rebar) is used for calculating the volume of iron.
To carry out the volume extraction process using BIM 5D - Based QTO, a 3D BIM model is first made. In general, the 3D BIM model for this quantity take-off can be obtained in two ways. The first is to directly use the Cubicost software to generate a 3D BIM model, by utilizing the Identify / Draw feature. This method can be called re-modeling a 2D working image into a 3D BIM model. Meanwhile, the second way is to take advantage of the interoperability between BIM Authoring Software, such as Revit, ArchiCAD, Tekla Structure, and BIM Quantity Take-Off Software, such as Cubicost. Thus, the 3D BIM model that has been previously created by Modelers with the Revit software, is then imported into the Cubicost software. For this research, a 3D BIM model was created in a second way.

The process flow of the quantity take-off of structural work (concrete, iron, formwork) with Cubicost software can be described as follows:

a) Creating a 3D BIM (Structure Model) Model
b) Importing the Model to the BIM Based Quantity Take-Off Tool
c) Performing the Quantity Take Off Process for Concrete and Formwork
d) Perform the Rebar Detailing Process
e) Carry out the Quantity Take Off Rebar Process
f) Implementation of Cost Optimization

The research object is the 8-floor tower building of hospital government “RSUD R. Syamsudin, S.H.” Sukabumi City which consists of 2 towers:
1) 1st floor for ER.
2) 2nd floor for Operation Room 18 theater.
3) 3rd floor for hemodialysis.
4) Floors 4 to 8 for Inpatient.

For this case study, 2 towers were taken for executives with quite a variety of finishes compared to the staff area. The Cost of worth analysis could be simplified as a study to identify the cost and worth of each of the structural item [27].

5. Discussion

The relationship between the results of the RII analysis and the analysis of the BIM case study based on the quantity take-off

In this discussion, we obtained a ranking of the ten factors that most influence the implementation of BIM-based on Quantity Take-off. Such as the responses of practitioners and related parties who became respondents favoring the image as the first order for implementing BIM based on Quantity take-off. Absolute image documents are the basis for calculating both manual and BIM-based Quantity take-off processes. Next is the BoQ, the document becomes a reference regarding the scope of work that must be calculated for the volume and price, the BoQ must be equipped with attributes and a description of the material specifications of the document, including the Work Plan Document and Terms and Conditions and other material information.

The next stage is the modeling process which requires qualification of BIM operators based on quantity take-off for office building fit-out work fields, respondents are observant enough to notice that the depiction and modeling of office building fit-out work have specificities that require operator experience or appropriate 3D modeling drafter. with the scope of work fit-out of the office building. Operators start modeling after first taking field measurements. The basis for making modeling are 2D design drawing data, Field Size, BoQ and scope of work, Individual selection mode.

Nos. 1 to 3 are quite clear, for number 4 the operator must first together with field engineering determine the method of modeling and the boundary of the model detail meeting to match the actual implementation. The next process after all the models are well-illustrated, the BIM process based on Quantity take-off can be carried out which is followed by a calculation process, the results of the Quantity take-off are only in the form of volumes that require unit price databases both from previous projects and renewable prices from suppliers.
and subcontractors. In the last order, operator education will be able to accelerate the BIM Quantity take-off process.

Following the type and character of work or materials in this study, not all parts of the BoQ produce different calculations, for example, items that are easy to count such as furniture and doors do not produce different calculations. Table 5 shows the QT output results from BIM Cubicost for wall finishing and table 4.17 shows the QT output results from BIM Cubicost for Rebar and concrete (Large size table is shown in the attachment). To increase the level of knowledge in BIM, it is recommended that many seminars and conferences be held which in consultation with the experts in the field of construction projects, on the other hand, to raise the skill level of engineers it is recommended to provide training programs in government centers and institutions. Building and supporting academic projects as well as encouraging researchers in the field of BIM will facilitate the transfer of expertise and information from the world. The government must play a vital role by providing the main guidelines to institutions in its transition toward BIM. The government can build a generation that knows about BIM by imposing a BIM curriculum in university education. The change towards the BIM should not be sudden and rapid as the presence of resistance to change must be addressed in several points, including providing training and application to small cases at first, this would break the psychological barriers and accept BIM.

The BIM Quantity-based take-off process takes a shorter time, about one-fifth of the manual take-off quantity time (Běčvarovská & Matějka, 2014). In addition to accelerating the BIM Based Quantity take-off calculation time, it also produces better accuracy, as seen in the results of the comparison of the BoQ for the fit-out case of office buildings, there is a difference in calculations, using BIM-based Quantity take-off results in smaller calculations that can be checked in Table 7.

Calculation of volume using BIM-based on Quantity take-off if calculated with the unit price, it produces the following differences: Initial BoQ Total Cost of Employment - BoQ BIM QTO results IDR 139,500,208,143, - - IDR 130,875,870,442 = IDR 8,624,337,701. The efficiency percentage obtained is 6.18% for the case of this project.

6. Conclusion

From the results of this study, the answer is that the stages of implementing BIM based on Quantity Take-Off are carried out by conducting Image Evaluation and Detailed Engineering Design (DED), followed by a location survey and BIM modeling and ending with a Quantity Take-Off, a point of attention to detail modeling and coding, material. The factors that affect BIM-based Quantity Take-off sequentially are Image, Completeness of Bill Of Quantity, RKS...
and Specifications, Cost Reduction, Activity Arrangement in Work Breakdown Structure, Cost Breakdown, Detailed 3D modeling, Interoperability Data, Subcont & Supplier pricing, and Cost database. In addition to accelerating the calculation time, BIM-based Quantity Take-off also produces better accuracy for concrete work, and rebar differences in calculations are obtained. The calculation using the BIM-based Quantity Take-Off results in a cost-efficiency of 6.18% for the case of this project. This hypothesis has been proven by statistical analysis and case study analysis by taking the research object of the Hospital Building.

**Abbreviations**

BIM : Building Information Modeling; BIM QTO: Building Information Modeling Quantity Take-Off; BoQ : Bill off Quantity; RII: Relative Importance Index; WBS: Work Breakdown Structure; CBS: Cost Breakdown Structure; QT: Quantity Take-off; TAS : Take-off for Architecture and Structure; and TRB : Take-off for Rebar.

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**Authors' contributions**

Conceptualization, A.E.H and M.M.; methodology, M.M, and D.I.R, analyzed, M.M, writing, M.M., editing A.E.H, M.M. and D.I.R, review, A.E.H. All authors have read and agree to the published version of the manuscript.

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