BIM Application in Construction Waste Risk Management

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\textbf{Abstract:} The construction process generates a huge amount of waste. If not well managed, this amount of waste will cause unnecessary risks for the project construction process in particular and for the environment in general. Therefore, many studies on waste risk management from the construction industry have been carried out. In recent years, BIM technology has been developed and applied a lot in the field of project management. In this study, the authors give a new perspective on BIM application in the field of project management - BIM application in construction waste management in the construction stage. The first part of the paper will present the research method, the literature review of the research. The final result is the result after applying the proposed research process. The final part of the paper will present the results of the study.

\textbf{Keywords:} BIM, Risk Management, Construction Waste Risk, Environment Impact

\section{Introduction}

One of the characteristics of the construction industry is the ability to consume resources and generate construction waste, especially waste from the construction site during the construction phase. According to research, 50\% of solid waste worldwide comes from the construction industry [1]. In which, construction waste accounts for about 10-15\% of the total solid waste generated [2]. According to the report of the National Target Program for the 2016-2020 period (thematic waste management) published in 2017 shows that the average growth rate of the construction industry in the period 2017-2021 is 8.5-8.7\% per year [3]. Moreover, the national GDP growth rate of industry and construction is the fastest compared to the agriculture, forestry, fishery and service sectors. From there, it can be seen that the development speed of the construction industry in our country is very fast, but there are also many potential risks in construction waste. Therefore, the roles and responsibilities of construction waste management need to be focused.
Construction waste generated at the construction stage has many types and huge quantities depending on the project size and nature of the construction work. If not well managed and handled, it will become a source of risks for construction projects and the environment. Therefore, governments around the world have developed laws and regulations related to this issue. Researchers have also been developing methods and frameworks for construction waste management. With the rapid development of technology, BIM has been widely applied in the construction industry, especially in the field of project management. However, research topics on BIM application for risk management due to construction waste have not received much attention. Therefore, the authors decided to choose this topic for research. This research topic is necessary and highly topical, the results of the research can bring certain values to future studies on BIM application for risk management.

2 Research method

First of all, the authors identified a research topic, realized that the topic of BIM application for construction waste risk management in the construction phase is a new topic, highly topical and research results can be considered. reference and serve to complete the scientific basis of BIM technology in the future. Therefore, the research team decided to choose this topic. Next is to determine the research object and research scope, thereby forming the research results to be directed to.
This study is applied a literature review method with the main purpose of identifying limitations in the current construction waste risk management process. Then, based on the limitations of the current process and combined with the risk management capabilities of BIM and the BIM uses available on the market today to find a suitable and effective BIM application direction. This baseline review begins by seeking answers to the following questions:

- What is construction waste (origin, classification, characteristics, ...)?
- What is the current risk management process?
- When is risk management most effective?
- What can BIM do?

Sources of documents providing information about the research topic include: manuals, books, articles and previous studies by domestic and foreign authors. Selected research articles were mostly published in the last 10 years. Therefore, the authors can understand the recent research trend in the field of risk management due to construction waste. From that basis, forming a theoretical basis for research on the BIM application process, BIM uses help support risk management due to construction waste. Finally, when the BIM application process and proposed BIM uses are completed. That proposed process will be tested in the pilot project to check the feasibility and limitations when put into practice. Process limitations will be improved in loops for more complete development.

3 Literature review

3.1 Definition of Construction Waste

The concept of construction waste first appeared in TCVN 6705 Standard: Ordinary solid waste - Classification in 2009 [4]. In Article 2 of TCVN 6705 standard, construction waste (or construction solid waste) is defined as "Waste discharged from demolition, renovation of old construction items/works, or from the construction process of classes new items/constructions (houses, bridges, roads...), such as lime mortar, broken bricks, concrete, porcelain water pipes, roofing sheets, plaster... and other materials ".

Figure 3: Construction Waste.
3.2 Risk Management.

Risk management: is the identification of project risk factors, quantification of risk levels and a plan to deal with and manage each type of risk [6]. Thereby, the risk management diagram is shown as the diagram below.

![Risk Management Diagram]

**Figure 4:** Construction Waste

Risk management is one of the nine main areas of Project Management. While a number of areas within this major area (such as Cost Management, Quality Management and Time Management) have been relatively common practice in the construction industry, Risk Management is being considered. is a relatively new field that needs more research.

3.3 Building Information Modeling – BIM

BIM stands for Building Information Modeling. According to BS EN ISO 19650-1-2018: BIM- “use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions”.

BIM is an innovative transformation in the design works. Unlike CAD, where 2D drawings will be taken as the basis for information extraction, BIM uses a digital copy model of the building. Therefore, when designing with BIM, instead of working with 2D drawings like the traditional way, engineers and architects will mainly work with BIM models of each discipline. Information such as 2D drawings, and design documents .. are all extracted from a single source that is from those BIM models. In addition, the exchange of information in the design also changes compared to the way CAD works. Information exchange will be held on CDE - Common Data Environment. This CDE will be the place to collect, store, manage, and disseminate all information, data, and documents created by the parties involved in BIM implementation in the project. This ensures that information in the design process is limited in error, information is dropped, the design uses the most up-to-date information, and most importantly, the coordination between the parties in the design is also effective.
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Figure 5: BIM models

4 Research result

4.1 Current construction waste risk management process

Knowing the limitations of existing construction waste management processes is fundamental to understanding the limitations. From there, evaluate the capabilities of BIM that can be applied to improve those limitations. To ensure coverage and objectivity, the studies were collected from many studies and articles on the Google Scholar search engine. Figure 5 below shows the current construction waste risk management process.

Figure 6: Current construction waste risk management process.
The current construction waste risk management process begins with the identification of risks posed by construction waste that may occur during construction. The result of this process is to identify the risk, for example, the information: the object causing the risk, the location of the occurrence, the cause... After the risk has been identified, a risk management program is in place. In this step, there will be risk analysis, risk assessment, and treatment plan... The final part of this risk management process is risk response. Currently, there are four options for responding to construction waste risks: waste generation, reuse, recycling and waste disposal.

### 4.2 BIM application in construction waste risk management

#### 4.2.1 Waste risk that BIM can assist in managing

BIM is a process that enhances coordination and interaction between stakeholder based on modeling and exploiting BIM models process. However, the potential and benefits of BIM are limited. Moreover, the risks caused by construction waste come from many causes, the causes can be divided into many types based on origin, treatment plan, impact on the environment, etc., so not any construction waste risk can be handled with BIM. Below is a summary diagram of risk sources due to construction waste that BIM can assist in handling [8]:

![Figure 7: Risk source of construction waste](image-url)
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4.2 BIM application in construction waste risk management

4.2.1 BIM application in risk identification of construction waste

Given the sources of risk mentioned above, the study proposes 5 BIM uses to assist in risk identification.

- Phase planning (4D simulation)
- Site utilization planning
- Design review
- 3D coordination
- Quantity take-off

![Figure 8: Risk Identification Process](https://example.com)

The proposed risk detection procedure is as follows. The BIM department can use the existing BIM model from the design stage to start the process. Or if there is no BIM model available, the BIM department must coordinate with the design department to create a BIM model of the project. Then apply BIM uses such as Design Review and 3D coordination to identify risks that could cause design changes on site.
After checking the risks in the design that have consequences for the actual construction process, the BIM department cooperates with the project management department to create a BIM model that simulates the construction organization and construction schedule. The management department must provide enough relevant information such as, construction progress table, quantity of materials in each stage... Then, exploit this 4D simulation BIM model and determine the causes. may cause risks due to construction waste based on simulation model.

The BIM model is integrated with the design information of the 3D BIM model, information such as construction progress, volume of coffa, scaffolding, etc. has been able to peel off the exact volume to help support the ability. Procurement is more accurate for each stage. Thereby avoiding backlog of materials.

BIM model quantity take-off can provide the ability to take off the exact quantity and total volume of construction materials, such as the volume of concrete to be demolished or the mass of components with potential for reuse without It takes too much time and effort like manual dissection. This BIM uses also helps in estimating processing and logistic costs in the future. As can estimate the number and size of pickup trucks and be able to compare the benefits of disposal and recycling. The quantity of each building material can be extracted from the as-built BIM according to the material type and building level. All quantified materials can be exported to Excel or other databases for mining if needed. With
BIM quantity take-off, the total demolition waste volume is 15.8% more accurate than other methods applied [8].

Figure 11: Waste quantity risk identification with BIM

4.2.2 BIM application in risk handling of construction waste

The risk treatment process begins with risk findings. These reports are the result of the risk identification process section 4.1 above. After that, the risks will be preliminarily assessed by the project management department and the BIM department. What risks do not need to be handled or cannot be handled with BIM tools have been identified, which risks can be handled with BIM tools. For risks that do not need to be handled by BIM tools, they can be transferred to other departments or project participants.

The process of handling risks due to construction waste is shown as shown below.

Figure 12: Risk handling with BIM process

The risks that can be handled by BIM are divided into 2 cases:
• Case 1: simple risk, small impact, can be proactively handled. In this case, the risk is within the scope of work of any department, the department is responsible for proactively handling and coordinating with the BIM department to update and modify the BIM model.

• Case 2: complex risks, great influence. In this case, it is necessary to organize an internal kick-off meeting for the parties to come up with a solution. The meeting requires the participation of all interested parties. After having a plan to deal with the risk. Stakeholders are responsible for coordinating with the BIM department to update the solution to the BIM model.

Below are the results before and after applying BIM to handle the risks of generating construction waste:

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The application of 3D coordination and the ability to visualize the design greatly helps in reducing the generation of construction waste. With BIM, the detection of anomalies and conflicts in the design when applying BIM becomes more efficient and less error-prone. Moreover, the ability to exchange design information between the parties involved in the design process is also enhanced. Thereby, the design quality is optimized, limiting design changes that lead to demolition at the site causing the generation of construction waste.

With the ability to direct construction field and manage construction progress in real time. Project management can easily make more effective decisions regarding the impact of construction organization and project implementation schedule. Thereby risks due to construction quality can be detected and handled easily. In addition, this can also help people without construction expertise to understand the plan of handling when encountering risks.

This is a compare formwork quantity take-off by manual measurement of beam and column formwork dimensions from 2D drawing and by automated take-off from BIM model. It is verified that the proposed algorithm can calculate quantity accurately and faster than the current Revit based and spreadsheet approaches. Besides, a BIM model with valuable information can be generated by utilizing visual programing.
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Figure 11: Handling the design that causes the amount of waste to be discarded at site.

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### Table 1: Comparison of formwork quantity and duration between manual and automated processes

<table>
<thead>
<tr>
<th>Formwork Elements</th>
<th>Manual Quantity Take-Off Area (m²)</th>
<th>Manual Quantity Take-Off Time (s)</th>
<th>Automated Quantity Take-Off Area (m²)</th>
<th>Automated Quantity Take-Off Time (s)</th>
<th>Deviations Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundations</td>
<td>262.45</td>
<td>04 min 11:44 s</td>
<td>262.45</td>
<td>01 min 07:36 s</td>
<td>0</td>
</tr>
<tr>
<td>Walls</td>
<td>2957.53</td>
<td>75 min 10:55 s</td>
<td>2957.53</td>
<td>08 min 45:77 s</td>
<td>0</td>
</tr>
<tr>
<td>Columns</td>
<td>558.22</td>
<td>110 min 05:26 s</td>
<td>558.22</td>
<td>06 min 28:32 s</td>
<td>0</td>
</tr>
<tr>
<td>Beams</td>
<td>580.36</td>
<td>90 min 08:13 s</td>
<td>580.36</td>
<td>07 min 44:55 s</td>
<td>0</td>
</tr>
<tr>
<td>Slabs</td>
<td>1375.59</td>
<td>31 min 55:43 s</td>
<td>1375.59</td>
<td>02 min 41:07 s</td>
<td>0</td>
</tr>
<tr>
<td>Stairs</td>
<td>93.90</td>
<td>20 min 45:36 s</td>
<td>93.90</td>
<td>07 min 39:45 s</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>5828.05</td>
<td>332 min 17:27 s</td>
<td>5828.05</td>
<td>34 min 28:12 s</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 13: Compare accuracy and time consuming between quantity takeoff by manual and BIM (automated process)

5 Conclusions and recommendations

Construction waste in particular and solid waste in general is a major global environmental problem. Countries around the world have implemented different policies and studies have been conducted such as recommending technologies and practices to reduce, reuse and recycle construction waste. However, the main causes of construction construction, such as inaccurate quantitative report extraction, inappropriate design leading to the risk of demolition on site, material procurement plan and construction organization unreasonable, inefficient use of materials, residues of raw materials, unexpected design changes.... BIM technology application in risk management of construction waste can be fully utilized to solve these problems. This study only considers the application of BIM for the purpose of risk management related to construction waste. However, there are other ways of doing
things, other areas that can contribute to the management of this type of risk, such as construction processes, materials management, planning, etc. Investors and design consultants should deploy BIM application early to achieve the best management efficiency. In the future, more in-depth studies should be carried out in other aspects of the construction project to better understand how to reduce, eliminate or reduce construction waste by other means. The results of the study indicate that although BIM cannot support the management of all risks caused by construction waste, BIM also has the potential to partially assist in reducing risks. Therefore, in the future, the authors aim to further develop the topic of construction waste risk management with BIM, for example, by developing better classification scales or expanding with standards in the field of construction waste management, national and international.

Due to the rapid development of the construction industry, the amount of construction waste has become a matter of increasing concern. Construction waste disposed of in landfills has grown exponentially over the years. Policy makers and engineers and architects practicing in the industry must raise awareness, make efforts to promote as well as implement effective reduction, reduction and management of construction waste. The emergence of BIM technology brings new opportunities to the field of project management in general and risk management due to construction waste by improving the quality of design and construction management with excellent applications, as the ability to visualize designs, promote cross-party communication, and coordinate multidisciplinary data. Therefore, a number of studies have focused on how to more effectively manage construction waste generated from the construction process with the help of BIM applications. With this in mind, this study investigated the existing challenges in applying BIM in the field of construction waste risk management and suggested future research directions to address those challenges. While it is certain that BIM can provide an environment that makes the design and construction process easier, allowing decision-makers to evaluate different design options or construction plans for risk management, risk from construction waste more efficiently. However, there are still many issues that need to be clarified before the effectiveness of BIM. This study brings a new perspective on the application of BIM in risk management of construction projects, specifically the application of BIM to manage risks caused by construction waste.

References


