Man-made Disaster Prevention using Waste Management Hierarchy and Disaster Management Cycle

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Abstract. The amount of construction waste generated is enormous due to the growth of the construction activities, which might lead to serious environmental problems. This is also including the construction waste that was generated from the natural disaster. This potential human-made disaster has been receiving worldwide attention and becomes a significant concern across nations. Thus, many studies on the effectiveness of construction waste management practices have been done. However, statistics do not show any improvement in the number of construction waste production. This paper aims to investigate the state of the art of construction waste management practice in Malaysia and the human-made disaster management strategies that feasible to be applied. Data were collected using the semi-structured interview with the key informants of the construction professional service providers in Malaysia and analyzed through thematic content analysis. An in-depth conceptualization and a new theoretical insight are developed on the strategy to prevent this human-made disaster caused by the construction waste. Findings from the cross-sectional content analysis and cognitive mapping propose a new human-made disaster management strategy in the construction caused by the construction waste that suits to Malaysian context.

1. Introduction

Human-made disaster or anthropogenic hazard is known as a hazard that caused by human action or inaction. A human-made disaster has the potential to injure and harm people, animals, and plants [1]. Apart from that, human-made disasters could also destroy and damage the whole earth's natural features, such as forest, lands, lakes, and oceans, if the activity conducted by the human action is not well controlled [1,2]. The definition of human-made disaster highlights that the effects of human-made disasters on every living thing on Earth must be stressed by all industry stakeholders, such as farming, manufacturing, and construction. Even though there is no concrete evidence that could manifest that

construction waste could cause disaster. Still, many scholars agree that a huge amount of construction waste might leads to serious environmental problems [3–6]; and increased the contribution to the global pollution [7] as most of neglected construction waste were dumped to sensitive area illegally [8], open burning and open dumping place [9]. Construction industry and natural disaster have reported producing a massive amount of waste which have given the adverse effects to several environmental severe problems [10–13]. Due to the adverse environmental impacts of waste generation, as well as financial gains associated with its minimization, waste intensiveness of the industry has remained a major concern across nations [14]. This issue gains worldwide attention [15]. Thus many studies on the ineffectiveness of construction waste management have been done [16–20].

Various studies have proposed everything that leads to high performing waste management to reduce the amount of construction waste on both predictable waste and accidental waste [21]. Studies have covered the policies, regulations, and acts [22,23], construction waste strategies [24], construction waste solutions [25], construction waste minimization approaches [26], and construction waste quantification instruments [27]. However, due to the lack of data on the construction waste benchmarking and statistics on construction waste generated [28] results to the inefficiency of the construction waste management [29] which leads to the difficulty in assessing the construction waste policy [21]. This is a result of having an inefficient construction waste management [16–20] that makes the list of the high performing construction waste management strategies go wasted. Meanwhile, for construction waste caused by a natural disaster, no comprehensive debris management plans, lack of available landfill capacity and pre-identified temporary debris management sites to manage large quantities of natural disaster debris contributed to delays in debris management after the hurricanes have resulting illegal dumping at the sensitive area like floodplains [8].

Therefore, this study would like to investigate the state of the art of construction waste management practice in Malaysia and the human-made disaster prevention strategies that feasible to be applied. This study used a qualitative approach to obtain an in-depth understanding of the real situation that happened on site regarding the construction waste management before the main study. It is needed as it focuses on "why" rather than the "what" to examine the natural phenomena of the research topic. This insight will help the researchers to understand the current state of the construction industry within the Industry 4.0 era and prevent the man-made disaster that could be caused by the excessive construction waste production as well as extend the recovery of the construction waste to avoid illegal dumping of the abundance of unattainable construction waste. This paper is structured as follows; Section 2 elaborates on the strategies for human-made disaster management in the construction industry that possible in the literature. Section 3 explains the methods used. Therefore, the next section provides reports and discussion of the results. Finally, Section 5 provides our conclusions and suggestions for future research.

2. Human-made Disaster Management Strategy in Construction

human-made disasters can trigger the natural disaster and escalate threats to humankind on a multitude of inter-related levels [30]. Thus, understanding how to cope the unpredicted disaster threats cannot be ignored. Therefore, enhancing disaster resilience in the construction industry is essential to reduce the risk of this human-made disaster [31]. Disaster exists in a continuum that is pictured by mitigation, preparedness, response, and recovery, in which the first two consist of catastrophe before the disaster strikes [32,33]. This cycle is called a Disaster Management Cycle (Figure 1) in the modern disaster management four-phase approach.

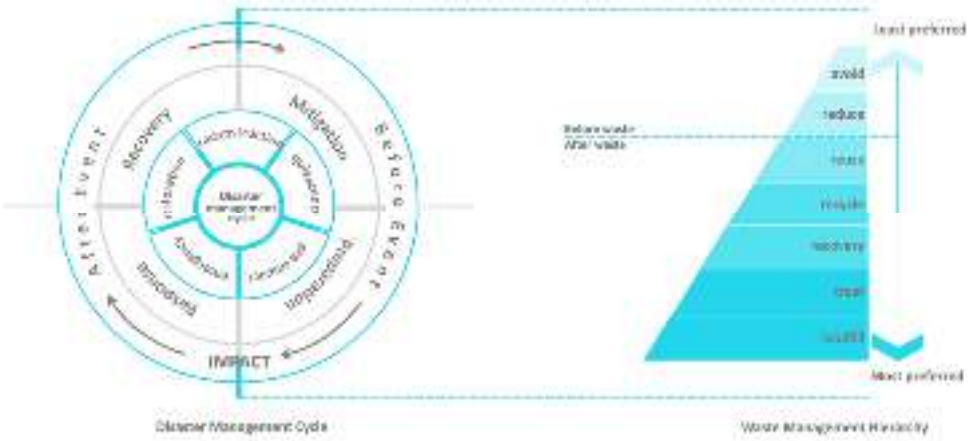

Figure 1. Disaster Management Cycle and Waste Management Hierarchy (adapted from [32,34])

Each of the approaches has different goals, and functions were 1) mitigation; known as a prevention that often considered as a cornerstone of disaster management which includes any action to reduce hazard risk through the reduction of the likelihood and the consequences component of that hazard risk, 2) preparedness; action was taken in advance of a disaster to ensure the adequate response to its impacts and the relief as well as the recovery from its consequences are performed in order to eliminate the need for any last-minute actions, 3) response; a function of emergency management includes actions aimed at limiting injuries, loss of life, and damage to property as well as the environment that are taken before, during, and immediately after a hazard event, and 4) recovery; the emergency management functioned by which countries, communities, families, or individuals to repair, reconstruct, or begin the loss which resulted from the disaster and ideally reduce the risk of similar catastrophe in the future [35,36]

In the waste management practice, Waste Management Hierarchy (Figure 1) has been established as the best waste management options. It is a widely accepted principle that has been interpreted and applied in waste management policies in different practical ways [37]. It is commonly described as 1) a priority order for waste management options, 2) based on assumed environmental impacts [38], and 3) offering the better environmental and economic benefits [27]. Waste Management Hierarchy ranks the options according to their environmental acceptability, with the most acceptable waste reduction and the least landfill disposal [39]. According to Yusuf [40], the first priority of Waste Management Hierarchy is a waste prevention where no waste has been produced yet, then followed by the reduction of waste production if waste must be produced, the third priority is the maximization of recovery, reuse, and recycling (3R Principle) of the suitable waste materials. The latter method being the most preferred option, is disposing of the waste to the landfill [41].

To prevent threat to the environment and humankind, it is necessary for the industry to avoid or maximize the amount of waste avoidance before the waste being generated. The integration of the disaster management cycle and waste management hierarchy is able to help in developing a new human-made disaster management strategy to avoid the possible human-made disaster caused by the excessive construction waste production (Figure 2). This new human-made disaster management strategy is divided into 2 phases; before waste/event and after waste/event. Similar to the disaster management cycle, the strategy starts with the activity that is able to prevent any waste production, or if the waste is exceptional, it must be reduced to lessen the damaging effects on the environment. The second phase will start when the waste has already been produced after the thought of reducing the waste has failed. This phase requires intensive waste recovery to minimize the amount of waste disposed to the landfill.

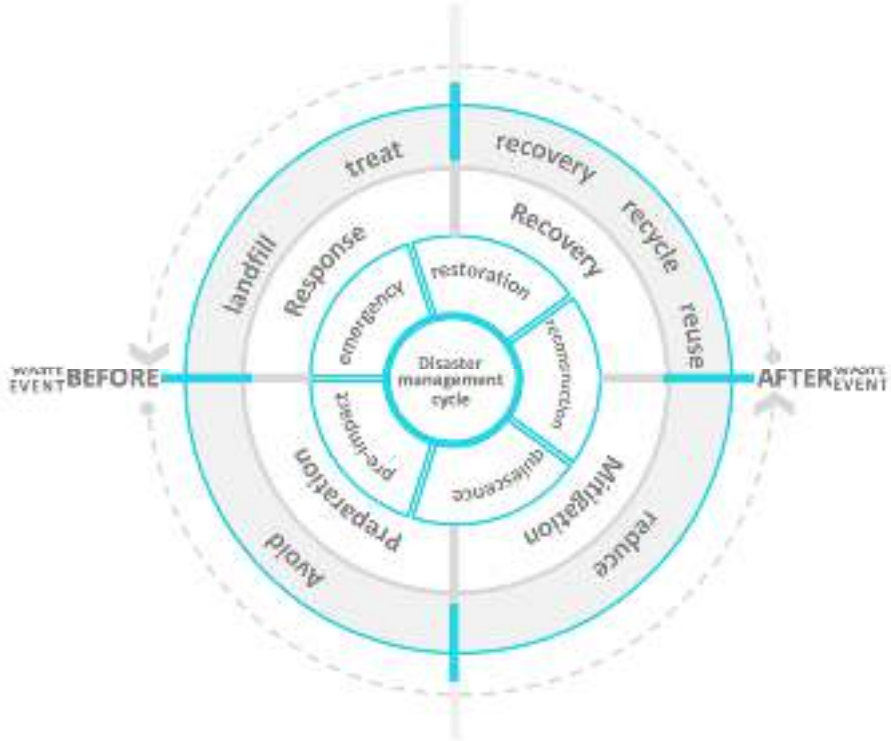

Figure 2. Human-made Disaster Management Strategy in Construction

To realizing the human-made disaster management strategy, it is essential for the construction stakeholders to adopt new technologies that can be used to enhance disaster resilience buildings. In the construction industry, Building Information Modelling (BIM) known for its ability to enhance the resilience of the built environment in the pre-disaster phase and post-disaster phase [31]. BIM is an emerging technology that is revolutionizing the global construction industry by demonstrating the value of computational data management in improving construction efficiency [42]. Internet of Things (IoT), on the other hand, offers the extension of BIM capabilities to enhance the construction operation and management [43]. The integration of these two technologies might be able to help in developing the human-made disaster prevention strategies that feasible to be applied.

3. Case Study

This preliminary study is conducted to understand the real situation that happens on-site regarding construction waste management prior to the main study to answer the object of this paper. This paper has undergone an extensive literature review on the strategies for the human-made disaster management prevention caused by the construction waste as well as the pilot case study.

Figure 3. Process Flow

Nine projects are selected as the pilot case study to understand the state of art of Malaysia's construction waste management practice. The projects are selected based on their availability of the construction waste management practice at the local authorities' jurisdiction that requires the waste management practice. This preliminary data collection was conducted until it reaches its saturated level, where no more spark new insights [44]. Audio and visual recordings were taken during the interviews to ensure that all of the information captured and thereafter verbatim transcribed. The questions are framed to

elicit the participants' thoughts based on their experiences in managing the construction waste. Findings from the interview were illustrated in Figure 4 to show Malaysia's most preferred construction waste management practice in comparison to the practices that were found in the literature. Understanding the state of the art of the construction waste is essential to develop the new human-made disaster management strategy in construction as a result becomes the input for the overall framework.

4. Data Gathering

As derived from the detailed analysis process of the content analysis, the cognitive mapping was drawn using NVivo, and open, axial coding. Some interconnections between the concepts and overarching themes were identified and grouped under the related themes. Figure 4 shows the result that came from the interview and site observation.

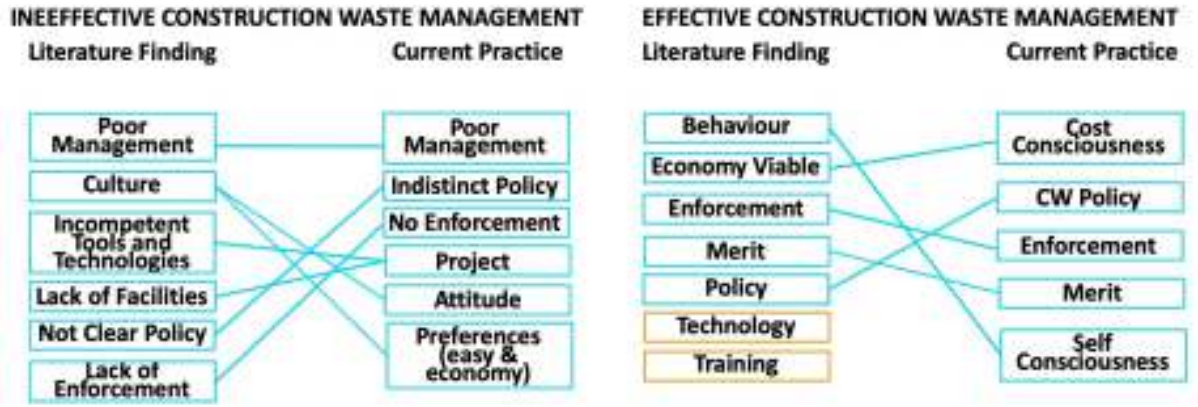

Figure 4. Current Malaysia's Construction Waste Management Practice

In summary, the findings further explicate that;

- Malaysia construction industry indeed has been facing ineffective construction waste management as most informants prefer to dump their waste to their site or landfill site without considering the impact on the environment,
- Evidence shows that there are some attempts to manage the construction waste efficiently by reusing and recycling the material/waste. However, there is no transparent construction waste supply chain to support this endeavor
- Construction waste in Malaysia is produced by phases, and each phase has a specific type of waste produced. This can help in developing the new strategy for human-made disaster management prevention.
- Technology and training that is missing from the current practice might be the answer to the increasing amount of construction waste generation in Malaysia.

5. Discussion

Construction waste is generated throughout the whole construction project life cycle, and it is inevitable. Above that, there was also construction waste that came from a series of unfortunate events such as floods. However, the strategy to avoid making more construction waste and extend its supply chain is necessary to prevent any human-made disaster caused by the construction waste. BIM, as a real-time interactive and collaborative communication system, has the potential to help the project stakeholders to attain a sustainable construction throughout the design stage collaboratively. Its capability was able to forecast waste through the integration of various models from different project stakeholders at the design stage until the construction stage. IoT, on the other hand, continues the task to monitor waste production at the construction stage. The strategy to monitor the production of construction waste using BIM and IoT is illustrated in Figure 5.

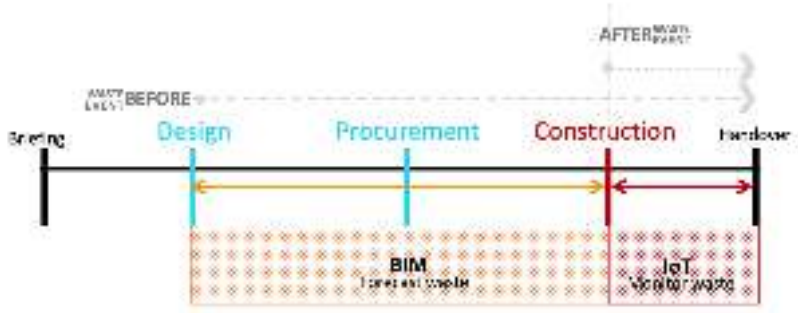

Figure 5. Strategy to Monitor the Production of Construction Waste using BIM and IoT

Figure 6 shows the construction waste avoidance/reduction strategy using BIM, where apart from the design decision, it also has the waste life cycle expandable strategy for the new material value chain. This requires architecture BIM model and structural BIM model at Level of Development (LoD) 300 and above for the material could be extracted at each construction phase into its quantification take off. Simultaneously, project stakeholders able to re-model the project when the projected construction waste is beyond the allowable cut-off point. The projected construction waste will be channeled out to the construction waste solution to the project for the new material value chain. This strategy could help the stakeholders to have some waste-conscious while designing the BIM model and could be able to prevent the human-made disaster caused by the construction waste.

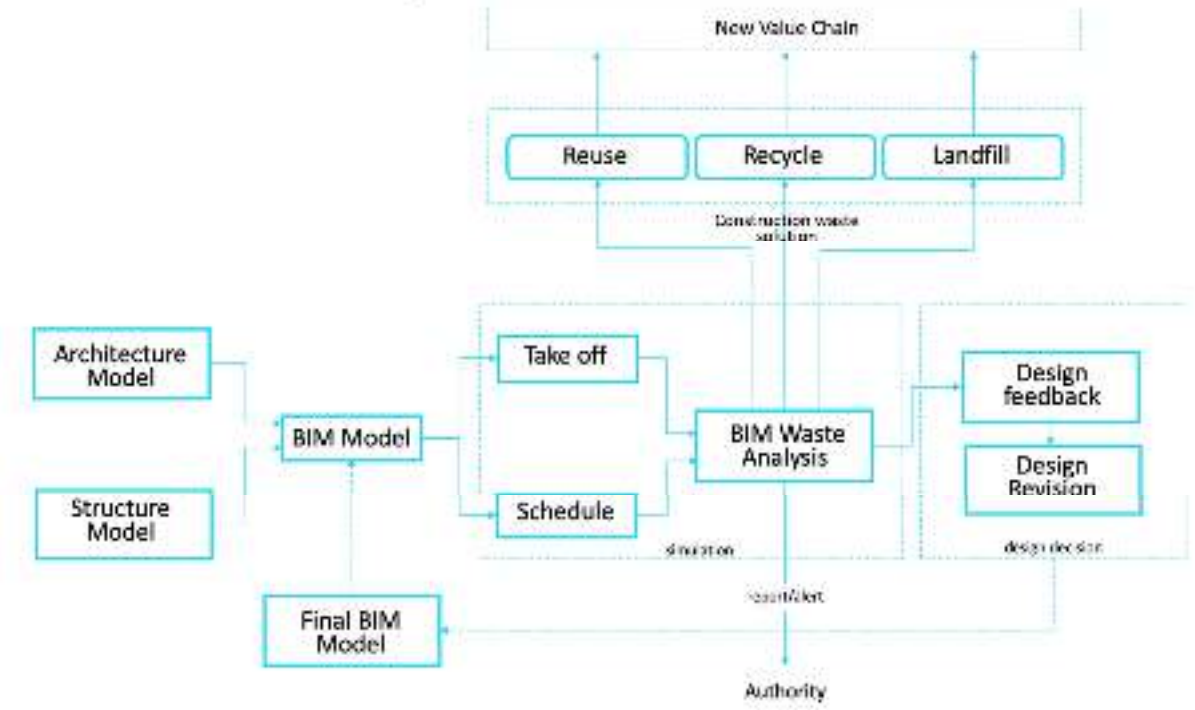

Figure 6. Construction Waste Avoidance/Reduction Strategy at Design Stage

During waste production (construction stage), IoT applications able to optimize the use of BIM. It increases productivity by improving waste management operations. It extends the BIM capabilities by monitoring the material handling on-site, segregates the waste on-site, monitors the operation of the project, and supervises the workers using the BIM model. This process could be done when the IoT Waste Analysis is coordinated with the BIM Waste Analysis (Figure 7). The innovation of IoT application also able to be extended to track down the routes, location of the truck, and the amount of waste carried by the trucks. This enhances the operation and data management for third party use, such

as local authorities, government agencies, and waste collectors. From the IoT Waste Analysis, the recorded data able to be channeled out to the construction waste solution to project for the new material value chain.

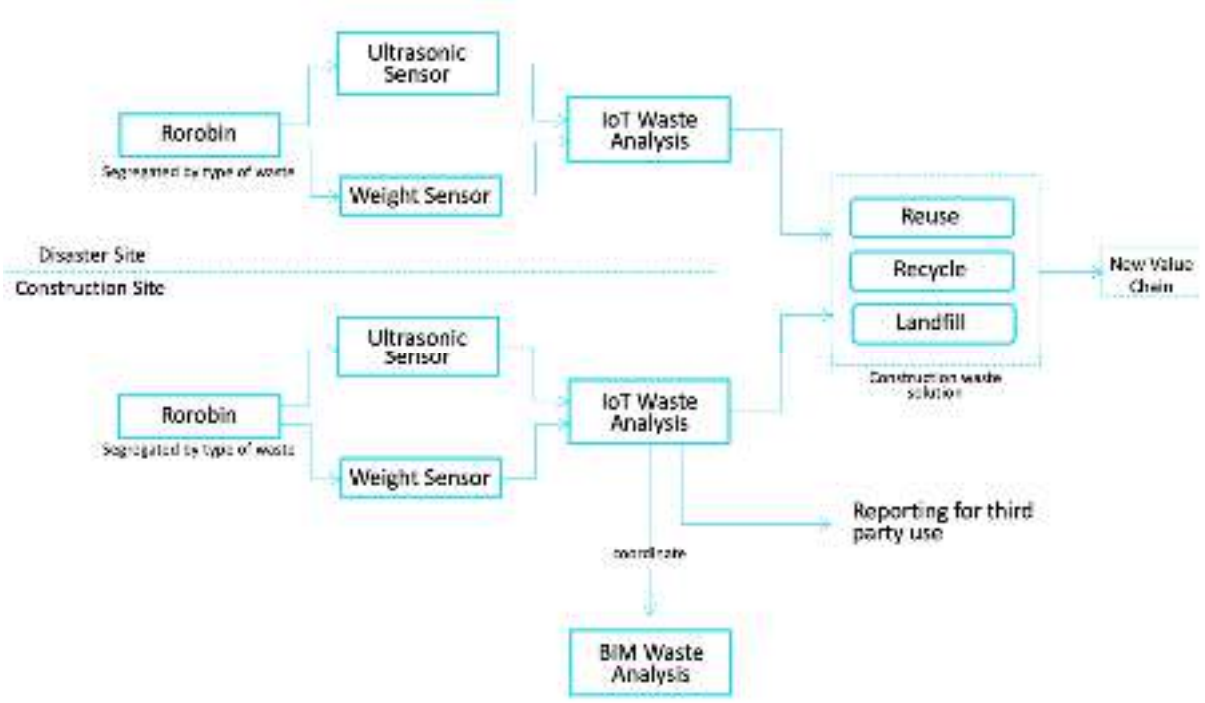

Figure 7. Waste Analysis Strategy at Waste Production Stage

With having the new value chain, a new product life cycle able to be created. This could help Malaysia to generate new income from the waste that previously was wasted in the landfill site that could cause possible human-made disaster. Figure 8 shows how from waste generated from building life cycle able to continue its life into new product when the waste is giving a new value. With having the Man-made Disaster Management Strategy in Construction, waste to wealth has the potential to be achieved, and human-made disaster is possible to be avoided.

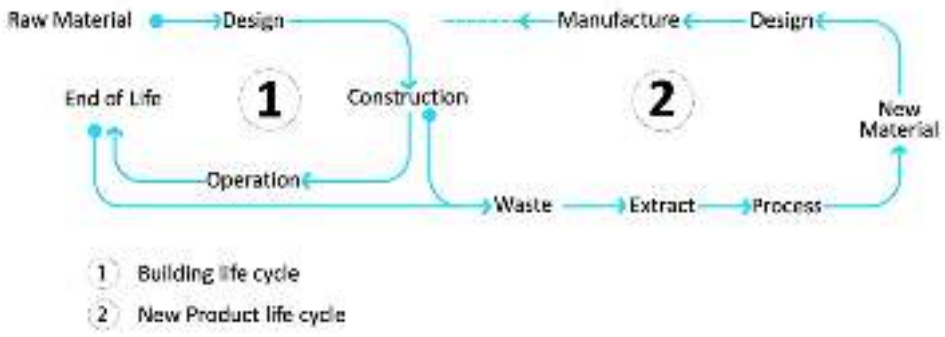

Figure 8. Proposed life cycle

6. Conclusion and future works

In this paper, we have discussed on Malaysia's construction waste management practice and has proposed a new strategy that is expected to be able to avoid or reduce the amount of construction waste generated before the construction starts as well as a monitor during the construction waste production. The challenge for the BIM model is to be able to quantify the construction material. Thus it must use LoD 300 and above to be able to forecast the amount of waste where different types of materials have different types of waste quantification methods. It is necessary to extract every material and propose a

specific quantification algorithm of each material in BIM. Materials that are expected to be able to be extracted using this simulation process are concrete, bricks, cement, and steel. The current BIM software that is able to pre-calculate the forecasted waste production is still under continuous research and development stage. So far, no said software has successfully able to project an exact accurate extraction of all materials in one single BIM model. Further research on a full BIM quantification process flow in a single BIM model is needed.

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