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# Identifying potential opportunities of building information modeling for construction and demolition waste management and minimization

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ABSTRACT

The amount of waste generated in construction and demolition (C&D) processes is enormous. Therefore, many studies on efficient C&D waste minimization and management have been conducted. However, 21 process-related and 8 technology-related limitations in C&D waste management and minimization have not yet been resolved. Building information modeling (BIM) helps project participants improve the processes and technologies in the planning, design, construction, and demolition phases, thereby managing and minimizing C&D waste efficiently. Therefore, this paper identifies the potential opportunities of BIM for efficient C&D waste management and minimization, such as design review, 3D coordination, quantity take-off, phase planning, site utilization planning, construction system design, digital fabrication, and 3D control and planning. The BIM-based approaches can support C&D waste management and minimization processes and technologies by addressing existing limitations through in-depth literature review. The roles of project participants and information required for each BIM-based approach in C&D waste management and minimization are discussed with illustrative process maps.



## 1. Introduction

Construction and demolition (C&D) waste is generally a mixture of surplus materials arising from construction, renovation, and demolition activities, including site clearance, land excavation, construction, roadwork, renovation, and demolition [1]. The amount of C&D waste is huge. For example, C&D waste made up over 25% of the solid waste disposed of at landfills in Hong Kong in 2014 [2], 48% in South Korea [3], and 26% in the U.S. [4]. Therefore, efficient management and minimization processes for C&D waste are greatly required.

Although many research has been conducted to improve C&D waste management and minimization processes, there are still many limitations in this area to be resolved, such as poor design quality [5,6], inefficient material handling [7], and poor procurement and planning [8]. Inappropriate design decision making and unexpected design changes were shown to increase the volume of C&D waste by 33% [9]. Therefore, these issues should be improved or eliminated for more efficient C&D waste management and minimization. Information and communication technology (ICT), such as spatial technologies, identification technologies, data acquisition, and data communication technologies, can improve or eliminate them [10]. Especially, spatial technologies can be used for routing and scheduling optimization, waste generation estimation, integrated waste management system development, risk assessment, and disposal site selection [10]. Building information modeling (BIM) is one of the spatial technologies as well as data communication technologies commonly used in the architecture, engineering, and construction (AEC) industry and can be systematically and efficiently integrated with identification and data acquisition technologies. A BIM model is a digital representation of physical and functional characteristics of a facility [11]. Since BIM models contain a wealth of information, such as material resources and geometry, and can be integrated with the schedule, cost information, etc., BIM provides improved planning and scheduling and helps to ensure Just-in-Time arrival of labor, equipment, and materials [12]. Integrated building design through BIM can avoid design problems and changes by improving coordination among project stakeholders [13–16], thereby reducing C&D waste generation. Better construction planning and management using BIM can also significantly reduce C&D waste generation by avoiding rework and unnecessary material handling and by efficiently using raw materials based on accurate measurement for material ordering, layout, and cutting. For example, BIM implementation has been shown to reduce rebar waste by 1.6% [17]. In addition, BIM-based design validation, which involves clash detection and design review, could reduce the number of design errors and rework, thereby reducing the amount of construction waste on site by 15% [18]. Rajendran and Gomez [19], Liu et al. [20], and Ahankoob et al. [21] introduced potential uses of BIM technology to minimize C&D waste. However, these efforts

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focused on C&D waste minimization using BIM in specific project stages and specific methods to utilize BIM for C&D waste management and minimization were not discussed. Liu et al. [22] proposed a design decision making framework for improving construction waste minimization performance, which can be used in the design phase of AEC projects. These previous studies did not consider all BIM uses that can be used in the planning, design, construction, and demolition processes.

Therefore, this paper aims to identify the potential opportunities of BIM for efficient C&D waste management and minimization in the planning, design, construction, and demolition phases of AEC projects. In order to understand the current status of C&D waste management and minimization, limitations in C&D waste management and minimization are identified and limitations that can be addressed by BIM implementation are analyzed through in-depth literature review. BIM uses that have positive influences on C&D waste management and minimization are identified, which are (1) design review, (2) 3D coordination, (3) quantity take-off, (4) phase planning, (5) site utilization planning, (6) digital prefabrication, (7) 3D control and planning, and (8) construction system design. This paper proposes their BIM-based approaches to efficient construction waste management and minimization, including how the limitations in C&D waste management and minimization processes and technologies can be addressed by implementing BIM in AEC projects, who should be involved, and which information should be generated and exchanged between project participants, through in-depth literature review.

The structure of this paper is as follows. Section 3 introduces previous studies on C&D waste management and minimization using traditional ways and using BIM. Section 3 also discusses the limitations in C&D waste management and minimization. In Section 4, BIM uses that can be utilized in the planning, design, construction, and demolition phases are identified to address the limitations in C&D waste management and minimization processes and technologies identified in Section 3. The ways to utilize the selected BIM uses to address the limitations in C&D waste management and minimization are proposed in Section 5, followed by discussion and conclusions in Section 6.

## 2. Research methods

To review limitations of existing C&D waste management and minimization and potential opportunities of BIM implementation to address these limitations comprehensively, a literature review-based approach examined both academic and applied publications. In the first step, in order to limit the research scope, a keyword search in Scopus and Google Scholar were conducted. Main keywords for identifying limitations in C&D waste management and minimization were word combinations between a word in a word list, including limitations, problems, obstacles, and challenges and that in a word list, such as C&D waste, construction waste, and demolition waste. For this, 41 journal papers, 1 conference paper, and 7 other publications were reviewed in this paper. Keywords to review potential opportunities of BIM for C&D waste management and minimization were word combinations between BIM and a word in a word list, including C&D waste, construction waste, and demolition waste. In order to identify potential opportunities of BIM for C&D waste management and minimization, 18 journal papers, 3 conference papers, and 10 other publications were reviewed in this paper. Based on existing BIM process maps, process maps of C&D waste management and minimization using the selected BIM uses were proposed, which included roles of C&D waste managers and information required for C&D waste management and minimization.

## 3. Limitations in C&D waste management and minimization

C&D waste minimization is generally classified into reduction, reuse, and recycling, collectively called the 3Rs, as shown in Fig. 1. Reduction is the first step to minimize C&D waste generation. If C&D waste generation cannot be avoided, generated C&D waste should be reused or recycled. C&D waste that is not reused or recycled should be disposed of at disposal facilities. This is the final step for C&D waste management. Efficient management of disposal waste is based on calculating the disposal waste amount, charging fee, and the number of required hauling trucks in advance and monitoring them. Therefore, precise estimation of the amount, type, and timing of C&D waste generation is fundamental to C&D waste management planning and execution for the 3Rs and waste disposal [23].

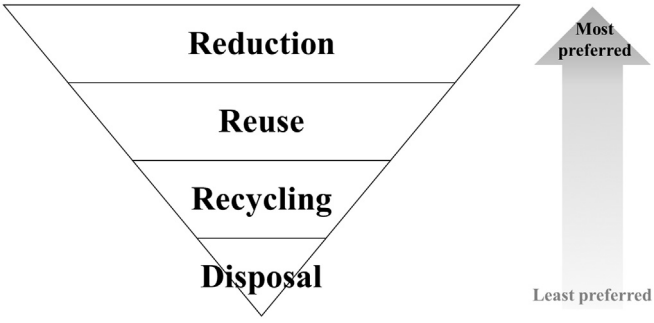


**Fig. 1.** C&D waste minimization and management hierarchy [24].

Although many previous studies have been conducted for efficient C&D waste minimization and management, there are still many limitations remained to be resolved. As shown in Table 1, 42 limitations in C&D waste management and minimization have been identified through in-depth literature review. The identified limitations can be classified, according to their characteristics, into three categories: process-related, technology-related, and policy-related limitations.

A process is a specific ordering of work activities across time and place, with identified inputs and outputs [25]. Processes, which include resources, activities, products, service, and leadership/management [26], are used to make people, policies, and technologies interact with each other. A process associated with C&D waste clusters a group of players who estimate, minimize, and manage C&D waste in the AEC industry. They include facility owners, architects, engineers, contractors, and wrecking teams involved in C&D waste management. The process category can be affected by the development of solutions from technology. This paper has identified 21 limitations as process-related issues via in-depth literature review, as shown in Table 1.

Technology is the application of scientific knowledge to practical tasks by organizations that involve people and machines [27]. It includes interaction between software and hardware for supporting C&D waste management in the planning, design, construction, and demolition phases of AEC projects in order to increase productivity and profitability. The technology category has influences on innovative solutions and new equipment in regard to policies and processes. Eight limitations related to technology in C&D waste management have been identified (Table 2).

Policies are written principles or rules for providing guidance on decision-making [28]. A policy includes the interaction of research, educational program, talent, regulations, guidelines, standards, contractual agreements, and best practices for C&D waste management. Examples are C&D waste charging schema, C&D waste regulations, vocational training in C&D waste management, etc. Stakeholders related to policy issues, including governments, research centers, educational institutions, and regulatory organizations, play pivotal preparatory, regulatory, and contractual roles in C&D waste management and minimization; however, they do not manage C&D waste directly. The policy category can change roles of experts who participate in the C&D waste management process. There are 13 limitations identified in this paper (Table 3).

This research focuses on investigating the potential opportunities of BIM to resolve the process-related and technology-related limitations in C&D waste management and minimization, because BIM-based approaches cannot directly improve the policies and guidelines in C&D

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