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# Building Information Modeling for Construction Waste Management

Keyurbhai Vadadoriya*
*Student, Department of Civil Engineering, University of Windsor, Windsor, Canada*

***Abstract*: Now-a-days, construction practices that have the potential to harm the environment are being carried out in an uncontrollable manner in order to meet the rapidly growing population's needs. Measures must be taken to maintain the world's ecological balance in the construction industry, which is one of the key sectors closely observing technological advances. The aim of skilled engineers is not only limited to constructing a building to meet engineering standards but also to do so in a manner that respects the environment. Numerous variables, such as incorrect design decisions, insufficient work schedules, unexpected weather oppositions, and defects in product supply, may influence the construction process actively or passively, leading to the production of construction waste on the construction site. Although it is theoretically impossible to fully eliminate construction wastes created during the construction process, these wastes can be managed and recovered. This technical paper looks into the potential of BIM applications in minimizing waste during the construction process. Different articles about the generation of waste during the construction process were studied.**

***Keywords*: Building information modeling, Construction waste management, 3D modelling.**

## 1. Introduction

The construction industry is a significant source of environmental emissions and energy use on a worldwide scale. Construction and demolition (C&D) waste generated at various stages of a construction project is one of the most damaging factors leading to the negative consequences of construction activities (Yuan, 2012). Massive amounts of greenhouse gases emitted, energy consumed, land occupied, soil and water polluted, and raw resources used to result in massive waste production, posing economic, social, and environmental problems in both developed and developing nations (Chooi Meh mah, 2016). As per the Us Environmental Protection Agency (EPA), reportedly 569 million tonnes of construction and demolition (C&D) debris were created in 2017, with the majority coming from concrete waste 69% and asphalt 15% ((EPA)., 2019). Steel, drywall, mortar, clay tile and brick, wood products, asphalt shingles, and concrete are all examples of building-related construction debris that are not included in municipal solid waste. Accurate construction waste management (CWM) will have various advantages, including lower landfill costs, lower greenhouse gas emissions, a decrease in the total of natural raw materials extracted, and conservation of land and water (Ling, 2011).

Building information modeling (BIM) has been used to optimize different aspects of C&D operations over the last decade. BIM provides owners with visual tools as well as comprehensive information on specific tasks and materials. As a result, measuring project life cycle costs on the BIM platform improves the efficiency and quality of the performance. Yuan and Shen calculated the cost-benefit of using BIM in CWM, taking into account both commodity rates, recycling and deconstruction costs, and income from selling salvage materials (Lu, 2011). The implementation of state-of-the-art metrics and activities in this study was heavily dependent on quantified measurements and estimations that could be used as benchmarks for construction industry decision-making (Lu, 2011). Despite the fact that much research has been done in the BIM-enabled CWM areas, there are still some major issues that need further investigation. The first is a failure to understand the complex existence of BIM for CWM, which contributes to missing existing potentials at various stages of a building's life; the second is a lack of adequate resources for making decisions on the various dynamic variables.

dimensions of BIM applications; and, ultimately, the third point is the requirement for a quantitative evaluation of BIM's capabilities in minimizing CWM expenses, which assists stakeholders and managers in estimating and budgeting calculate the true cost and gain of CWM. Besides, it is crucial to stop construction waste on construction sites in order to avoid economic and environmental losses and that can be done by the correct use of BIM in construction. Despite the fact that it is a relatively new technique, it is steadily gaining acceptance among construction professionals.

## 2. Literature Review

This matrix study identifies results from previous researchers from all over the world. Eleven research papers were analyzed for this study. By studying these papers, 24 factors deemed significant for the generation of waste on the construction site and these factors are classified into six categories which are design, communication, materials, planning, laboring, and external factors.

*Corresponding author: vadadoriya.keyur45@gmail.com

Table 1
Causes of waste generation as identifies in literature (Burcu Salgın, 2017)

| Category | Causes of Waste Generation / References | Bossink& Brouwers (A. G. Bossink, | Garas et al. (L. G. Garas, 2001) | Alwi et al. (S. Alwi, 2002) | Ekanayake & Ofori (L. L. Ekanayake, | Polat & Ballard (G. Polat, n.d) | Poon et al. (C. S. Poon, 2004) | Tam et al. (V. W. Y. Tam, 2007) | Wang et al. (J. Y. Wang, 2008) |
|---|---|---|---|---|---|---|---|---|---|
| Designing | Last-minute changes | • | • | • | • | • | • | • | • |
| | Designers' lack of knowledge | • | • | • | • | • | | | |
| | Design errors | • | | • | • | • | | • | |
| | Complicated design | | | | • | • | | | |
| | Poor design quality | | | | | | | | • |
| | Lack of environmental awareness | | | | | | | | • |
| Com. | Lack of coordination among parties | | • | | | • | | | |
| | Lack of communication among designers | | • | | | • | | | |
| Materials | Poor material handling | | • | | • | • | • | • | |
| | Ordering errors | • | • | | • | • | • | • | • |
| | Poor quality of materials | • | | | • | | | • | • |
| Planning | Wrong material storage | • | • | | | | • | • | • |
| | Poor site management | | • | | • | • | | | • |
| | Poor planning | • | | | • | • | | | |
| | Lack of waste management plans | • | • | | | • | | | |
| Laboring | Workers' mistakes | • | • | | • | • | • | • | • |
| | Damage during transportation on site | • | • | | • | | | | • |
| | Lack of knowledge | | • | | | | | | • |
| | Lack of experience | | | | | | | | |
| | Shortage of skilled workers | | | | | • | | | |
| External Factors | Effect of weather | • | | • | • | • | | • | |
| | Accidents | • | | | • | • | | • | |
| | Theft | • | • | | • | | | | |
| | Vandalism | | • | | | | | | |

According to Table 1, the element with the highest frequency is last-minute design changes. Table 2 illustrates significant factors for all categories which are frequent in literature so they are described.

Table 2
Categorization of major factors that contribute to waste generation categories

| | **Major Factors** |
|---|---|
| Communication | Lack of coordination |
| Designing | Changes that occur during last minutes |
| Planning | Storage of wrong material |
| External Factors | Weather effects |
| Materials | Ordering errors |
| Laboring | Mistakes of workers |

*1) Lack of Coordination Among firms. (Burcu Salgın, 2017)*

There will almost certainly be design flaws if the project stakeholders involved in building projects (contractors, designers, and clients) do not communicate well with one another. Finally, due to a lack of teamwork, waste may pile up on construction sites. Such wastes can be avoided with good communication among team members.

*2) Changes that occur during last minutes (Burcu Salgın, 2017)*

These concerns arise as a result of some client requests for changes, especially at the last minute. The client and the designer must agree on the design at the design stage, and they must make the final decision together before the contractor begins construction. If this is not completed, adjustments can be made during the building process when issues with the drawings arise.

*3) Storage of wrong materials (Burcu Salgın, 2017)*

Waste may occur as a result of improper stacking and storage. When products, such as bricks/blocks or bags of cement, are stacked without pallets or improperly stored in an open space without proper protection, bad weather conditions, such as rain, can result in material waste. To eliminate generation of waste on construction sites, proper material storage is essential.

*4) Weather effects (Burcu Salgın, 2017)*

Changes in weather patterns are one of the parameters that humans cannot monitor because they are a natural phenomenon. Unforeseen conditions trigger weather changes. As a consequence, good management skills can be used to minimise wastage caused by such events (Odesola, 2015).

*5) Ordering errors (Burcu Salgın, 2017)*

It is indeed essential to order materials in the correct quantity to avoid shipping materials in excess, which could result in waste. This can be accomplished by properly estimating materials both before and during the project's execution (Anon., 2011)

*6) Mistakes of workers (Burcu Salgın, 2017)*

One of the primary causes of waste on construction sites is workers' insufficient knowledge of how to handle materials. As per Lingard et al. (H. Lingard, 2001), in order to achieve the 3Rs (i.e., reduction, reuse, and recycling), managers must learn to focus on the actions of construction workers while handling materials. In their research, Tam and Tam (V. Tam, 2008) discovered that offering bonuses and benefits to employees resulted in a 23 percent waste reduction. As a result, it is critical that company plans facilitate waste reduction training for employees. The policies should also raise awareness and inspire contractors to use waste-reduction techniques in their work.

### 3. Strategies for Reducing Construction Waste on Construction Sites (Burcu Salgın, 2017)

In waste management, waste reduction is a critical factor. Any action that reduces the amount, supply, or environmental effect of waste is referred to as "waste reduction."

The benefits of waste minimization are as below:

- Reducing the amount of space in landfills,
- conservation of natural resources,
- conserving electricity
- Pollution reduction several approaches have been used around the world to achieve these benefits. The use of a BIM-based site management approach is one of the most important of these methods. Construction industry professionals are generally optimistic, claiming that BIM can improve project construction results by reducing mistakes, omissions, and disputes. Studies on the use of BIM in construction site management for construction waste prevention /reduction look promising and potential, despite a paucity of literature.

### 4. Current Practices for Waste Reduction (Alireza Ahankoob, 2012)

Many studies have been undertaken in an effort to minimise material waste on construction sites, but developing a method to avoid waste during the design and pre-construction stages has proven to be difficult. Consideration is still needed. According to Agopyan et al. (1998) the waste generators' lack of awareness is a problem remarkable source of waste. Furthermore, there is no predicting and dependable approach and method to forecasting and assessing the volume of construction waste until work begins on-site (Formoso, 1999).

However, the study of waste sources revealed that a significant amount of waste is produced as a result of flow activities, such as such as material supply, inventories, and internal controls handling and storage (Formoso, 2002) .

Prevention and management of waste causes may help to reduce environmental impact while increasing profits. Furthermore, using a technique that is focused on meticulous preparation, tracking, and control. A system in place will assist in avoiding or reducing the discarded building materials. The following flowchart is a step-by-step guide approach to waste reduction.

The concept that contends waste reduction intervention should concentrate on pre-construction stages, especially design, where virtual waste (simulated waste by BIM) exists. As compared to real technology, waste (on-site physical waste) may be easily recycled established, estimated, and decreased. BIM is advantageous because it offers an accurate model of the design as well as the material resources needed for each section of the job. Provides a foundation for better planning and scheduling subcontractors and aids in ensuring just-in-time delivery in terms of staff, facilities, and materials. The model can also be used in accordance with wireless hand-held computers to aid in material tracking and installation. In the sector, there is progress and automatic positioning. The formalized paraphrase ability to imagine the shape and assess function. The rapid generation of design alternatives, as well as the maintenance integrity of knowledge and concept model (including reliance on a common source of knowledge and conflict checking), as well as automated report creation, all results in more consistent and reliable data that greatly benefits reduces the waste of rework and waiting for results particulars.

In the design stage, a large amount of construction waste is produced as a result of the construction system, material choices, and design process (C.S. Poon, 2002) . Changes in design approach are the most efficient way to reduce construction waste. Design choices and approaches may have a direct impact on waste reduction during construction, as well as the re-use and recycling of construction materials. BIM's ability to incorporate the modeling, coordination, cooperation, and alignment of sustainable design and construction criteria and actions across all project lifecycles will be enhanced by the developed knowledge management associated with BIM for construction information.

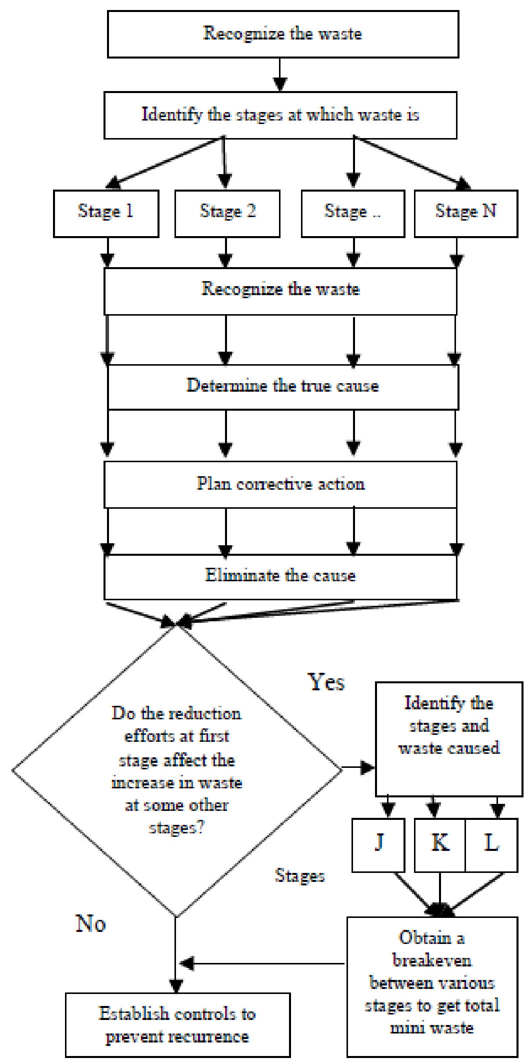


Fig. 1. A systematic approach for waste reduction (Meghani, 2011)

### 5. BIM based Waste Estimation and Planning System (Varsha Ashokkumar1, 2018)

BIM stands for Building Information Modeling, which is the method of creating and using a digital computer building model to simulate and control the planning, design, construction, and operation of a structure. The resulting building information model is a digital representation of the facility that is data-rich, object-based, intelligent, and parametric. BIM software is needed to build a BIM model. BIM software is currently provided by a number of firms, including Autodesk, Bentley Systems, Nemetschek, and Graphisoft. Autodesk Revit Structure is used in this study to demonstrate the construction of a 3D BIM model. Users can manipulate the entire building in the Revit setting. Figure 1 shows a flowchart for creating a 3D BIM model in the Revit setting for calculating waste generation during the design and construction stages.

### 6. BIM Application on Waste Reduction (Alireza Ahankoob, 2012)

Material waste and spoilage is significant issue in the building construction industry and is inherently unsustainable in both environmental and economic terms. BIM encompasses the primary source of waste generation and removes non-value-adding practices that are neither compatible nor essential. This new technology allows all project participants to see exactly how materials and equipment are laid out, how activities are carried out, and how differences between building elements are resolved. Baldwin et al. (2008) used design knowledge modeling to test prefabrication and pre-casting as options for reducing construction waste in high-rise residential buildings. They came to the conclusion that BIM is a successful forum for improving construction waste analysis and the consequences of design decisions. Furthermore, with the help of Virtual Prototyping, BIM provides a design team with a platform to assess the effect of design decisions on the overall construction process. On the other hand, it is generally accepted that combining BIM with the creation and application of 3D virtual building modeling techniques and technologies will produce extremely beneficial results.

The following are the basic BIM waste reduction solutions:

*A. Conflict, Interference and Collision Detection*

By using visual technologies to inspect for all interferences, clashes, and collisions, BIM helps to minimize conflicts. Because of this, BIM will act as a consultant for designers and engineers.

Models can be thoroughly scrutinized, simulations run easily, and efficiency benchmarked (Azhar, et al., 2008). The use of 3D visualization improves communication and comprehension (Young Jr, 2009). Minimal design adjustments after construction ensure that the project is completed on schedule and on budget.

*B. Construction Sequencing and Construction Planning*

BIM may be used to construct a timetable for purchasing materials, fabricating them, and delivering all of the building components. Just-in-time delivery of materials and equipment is possible thanks to precise programme scheduling, which reduces the risk of injury. The use of BIM for automated equipment and component fabrication allows for more effective materials handling recovery.

*C. Reducing Rework*

Since the issues are resolved early in the design phase, there will be less contentious issues in the plans and fewer difficulties (Young Jr, 2009) . Any concept changes made to the building model are revised automatically. As a result, rework due to potential drawing errors or omissions would be reduced. More than 80% of those polled by McGraw Hill Construction (2009) agreed that reducing rework is important, and BIM can help with that.

*D. Synchronizing Design and Site Layout*

By connecting the 3D objects in the design model to the construction plan, a simple procedure of activities is created, allowing the building and site to be seen at any point in time (Eastman, 2008). The arrangement of equipment and material is precisely considered by BIM 4D modeling, and everyone involved in the project knows where the material should be put. This capability would reduce the amount of extra handling, excessive moving, and material waste.

*E. Detection of Errors and Omissions (Clash Detection)*

This is the most frequently mentioned method for owners to save time and money by using BIM (Young Jr, 2009). Any improvements made in one drawing are not reflected in other similar drawings in 2D drawings.

As a result, there are many inconsistencies and, as a result, many mistakes and omissions. Many of these mistakes are discovered only after the work has begun on the site, which may result in several site conflicts, legal disputes, and change orders. The use of BIM, on the other hand, removes these problems.

Conflicts are recognised until they occur on site, resulting in improved coordination between designers and contractors. Error detection expedites the design process, lowers costs, avoids legal conflicts, and offers a smoother project process (Eastman, 2008).

*F. Precise Quantity Take-Off*

The term "exact quantity take-off" refers to the fact that materials are not over-ordered.

Planners and engineers may use this technology to get an accurate estimate for the right material order. As a result, there will be no additional products on site that may be mobilized due to bad weather or movement.

### 7. Conclusion

The papers in this review explored the relationship between BIM technology and construction waste management practices in depth. The methods explored the use of BIM technology in the reduction of construction waste on construction sites. The construction process was the only subject of this study; however, the design and post-production phases of the project life cycle were left out. BIM technology is a technical advancement that can be very useful in construction waste management, according to all of the articles reviewed. The report, however, found no current BIM-based site management techniques for construction waste reduction. This is mostly due to the fact that BIM is a new technology, and it is believed that plug-ins to help construction waste management have yet to be created. The possibilities of technology are expected to minimize the construction waste that is created consciously and/or unconsciously during the construction process. At this time, it is believed that BIM technology, which allows for the creation of the entire project on a digital interface, can be used in a systematic manner.

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