The on-site waste minimization practices for construction waste

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Abstract. Rapid development in construction industry had caused the increasing of construction waste. This situation brings many negative impacts towards the environment, cost, productivity, time, social and economy. The increasing of construction wastes is mainly due to the inefficient waste management practices in the construction projects. Hence, the effective management practices in handling construction waste should be highlighted. This study seeks to identify the waste management practices that are able to engender on-site waste minimization. As much as 54 practices had been found from previous research publications. Mapping technique was used to determine the frequency for each practice. This study have found five (5) significant management practices that need to be emphasized in order to achieve on-site waste minimization. The findings of this paper will help researchers to further investigate the significant management practices in minimizing on-site construction waste.

1. Introduction

Construction industry is very important in every developing country. The construction industry is an economic investment and its relationship with economic development is well posited [1]. Both developing and developed nations have realized and comprehended the important of construction industry in socio-economic level and sustainable development of a country. It plays a vital role towards a growth of a nation by providing essential infrastructures and physical structures for activities such as commerce, services and utilities [2]. The development of construction sector is a part of the living environment which is affecting the living conditions, social well-being and health. The industry also engenders employment opportunities and inject money into nation’s economy [3]. However, despite of these contributions, rapid development of construction industry has led to the increasing of construction wastes and this situation had become one of the serious issue in Malaysia.

Generally, construction waste is defined as the unused products or materials which resulted from construction activities during pre-construction, construction and post construction phase [4]. In addition, Tam et. al, [5] stated that construction waste is defined as any unwanted products from the construction, renovation and demolition works. Meanwhile, Shen et. al, [6] mentioned that construction wastes are any building materials, concrete, steel, timber and other material which are resulted from various construction activities. It can be concluded that construction waste is the excess materials generates from the construction activities. In Peninsular Malaysia, the amount of solid wastes generated per day increased from an estimated 23,000 tonnes in 2010 to 25,000 tonnes in 2012 [7]. Currently, Solid Waste...
and Public Cleansing Management Corporation of Malaysia confirms that approximately 8 million tonnes of construction wastes per year generated from construction projects [8]. The increasing of construction wastes is caused by inefficient waste management practices in the construction projects [9]. All the construction wastes that produced from construction activities will cause negative impact towards surrounding environment, cost, productivity, time, social and economy [10]. In construction industry perspective, this issue will contribute to the value reduction of construction productivity and reduce the performance of overall projects.

Based on the discussion above, an effective construction waste management is the solution to overcome the issue. According to Yuan [11], construction waste management is one of the sustainable development approaches to minimise wastes and to avoid negative impacts on the environment. It is necessary to highlight construction waste management in order to provide mutually beneficial to the environment, society and the economy. Hence, this paper seeks to identify construction management practices which will cause the minimization of on-site construction wastes.

2. Construction waste management

The increasing awareness regarding environmental impacts from construction wastes has led to the development of waste management as an important approach for construction project management. Managing construction wastes is vital in order to cope with future sustainable development. The practices of waste management for construction activities comprised with the aim to protect the environment and with the recognition that wastes from construction and demolition works contribute significantly to pollution of the environment [6]. Fauziah & Agamuthu [12], defined waste management as the discipline that encompasses solid waste generation, storage, collection, transport, processing, and disposal by considering the environmental, economic, aesthetics and public concerns. In addition, the management of waste includes monitoring, collection, transport processing and waste disposal.

There are many efforts that have been carried out by the Malaysian government to minimise the generation of waste. Nevertheless, many contractors failed in implementing good waste management which led to the mismanagement of construction waste [13]. There are several approaches to construction waste management. The process of managing construction waste goes far beyond the disposal of the wastes itself. It is encompassing a strategy to effectively utilize construction resources, with the view to reduce the quantity of waste and utilizing the generated waste in the most effective manner. In Malaysia, disposing the wastes directly to landfill sites is the most common approach in managing construction wastes. This method is chosen among contractor in Malaysia because the waste materials is assumed to have a little premium value. However, the practices will no longer be applicable for a long term since construction industry had generated significant amount of wastes and there is increasing of construction wastes year by year that will further congest the already over-flowing landfills. As the evidence, it was reported that among 289 landfills which also includes dumpsites, 113 of these landfills are no longer in operation due to protest from surrounding residents or have reached their full capacity [14]. This has prompted the need for alternatives of waste prevention and the initiatives to reduce, reuse and or recycle wastes produced which are referred to as the 3R’s of construction waste management.

![Waste management hierarchy](image_url)

Figure 1. Waste management hierarchy [14].
Basically, construction wastes need to go through a pre-treatment process before being disposed to landfills. It should be treated according to proper waste management hierarchy as shown in Figure 1 [14]. There are 3R concepts in waste management that need to pass through before being disposal at landfills. The criteria of waste management started with waste reduction, reuse, recycling and lastly disposed to landfills. The process of construction waste management at the end will end up at landfill [12]. Hence, it is vital to effectively utilise the construction resources in order to reduce the generation of wastes.

2.1. Reduce, Reuse & Recycle Strategy
The term of waste reduction is related with the practices to reduce waste generation at it source. This ensure waste is minimized before it become much bigger problem. In construction project, it could be achieved through reducing or avoiding any activities and process that caused waste generation. As early as the planning stage, the reduce strategy can be implemented and continuously embedded throughout the construction lifecycle [15]. The reduction in construction waste is considered the most effective and efficient method to manage construction waste. But, it is an utmost important to recognize the influencing factors in waste generation before the reduce strategy can be implemented. These factors comprised of design changes, poor material handling, lack of capability among the labours, poor management planning, poor site condition, procurement of construction material and external factor (weather) [16].

Reduction of construction wastes at its sources not only able to reduce waste generation, but also reduce waste transportation costs, waste disposal and waste recycling. Even in the most sustainable construction site, waste can’t be eliminated totally. The site definitely will produce certain types of waste and this waste is called as unavoidable waste. Since the waste generated is not fully avoidable, the next step should be considered is to reuse some of the construction waste materials such as using broken brick and concrete as a sub-grade of access road to the construction site [14]. In addition, [15] stated that reuse is defined as the using of construction resources which is the material, such as timber formwork, more than once either by means the same function or not. Recycle strategy is defined as a process of collecting the used, re-used and also the unused things that already considered as waste but turned into usable new item [17]. At site, these items are sorted inside the construction site or off-site and will be sent to processing centre to be turned into raw materials or re-manufactured into new or same products. The sorting of waste for recycling purposes could be done as an on-site or off-site waste management technique.

According to [18], the on-site recycling technique is the isolation of the construction waste and then is used as a raw material in other construction processes. Meanwhile, the off-site recycling technique is the separating and transporting of the construction waste to other organizations so that it can be use as the raw material. Government participation is crucial to ensure a successful recycling program in the construction industry. Recycling will not only reduce negative impact to the environment but also will ensure the availability of the materials in the future.

3. The on-site waste management practices
Mapping method of practices is adopted from [19], in order to provide preliminary idea on what past researchers had discovered regarding construction waste management practices that contributed to on-site construction waste reduction. The matrix analysis identified the most prominent practices based on the frequency of the measures which identified by past researchers around the world. Through a review of the identified literature, some site management practices for engendering construction waste minimization are identified as presented in Table 1. All of the stated site management practices for successful on-site waste management in Table 1 are most likely suitable and applicable to be implement in the construction project within Malaysia.

As much as 54 measures for successful on-site waste management are identified from 20 literature review on the research articles. The measures are divided into 5 management groups which are Human Resources, Material and equipment, Construction method, Administrative and Regulation. The grouping for construction management practice is adapted and modified from [20] research. There are 4 measures in Human Resources management group, 9 measures in material and Equipment group, 19 measures in
Construction Method group, 17 measures in Administrative group and 5 measures in Regulation management group.

4. Mapping process and analysis of the on-site waste management practices

Based on the on-site waste minimization management practices in Table 1, the highest frequency for the waste minimization practices are presented in Figure 2 with accordance to the code given.

Based on the Figure 2, the most significant practices to minimize on-site construction wastes is A1 (Human resources group) practice following respectively by E1 (Regulation group), C1 (Construction Method group), D1 (Administrative group) and B1 (Material and Equipment group). In ‘Human and Resources’ group, 18 out of 20 researchers agreed that education and awareness is the important factor to engender waste minimization. A study by [38] found that the major barrier in the industry is the lack of awareness among local contractors, construction labor and architects about waste management techniques and approach. They perceived that conducting construction waste management usually will increase the project costs and therefore will reduce company profits. The construction practitioners are giving more focus on the cost, time, and the quality specified in the contract, less attention is giving towards waste reduction [39]. Thus, the construction industry practitioners’ awareness regarding resource saving and environment protection is a vital driver for construction waste minimization. Education and awareness aspect regarding waste management at site will lead construction actors to implement effective practices in reducing generated wastes. However, the awareness of having a proper management of construction wastes is still lacking in Malaysia. Hence, there is an urgent need to improve the education and awareness of construction industry practitioners in Malaysia.

The second highest frequency of on-site waste minimization practices is E1 which is the usage of off-site products and components in construction project. In ‘Regulation’ group, as much as 16 researchers admitted that this practice is able to provide directly waste minimization at site. Construction Industry Development Board (CIDB) Malaysia, has been dynamically encouraging the practice of industrialized building system (IBS) and other off-site construction techniques in local construction industries since 1998 as a method to overcome construction waste problem, conserve landfill capacity and also helping to achieve the concept of sustainability [40]. Waste reduction is one of the major benefits when using this practice compared with conventional construction. According to [41], the off-site construction techniques such as prefabrication, is perceived as a solution to major causes of waste generated during both the design and construction stages. This practice also contributes to other benefits on-site such as improved quality control, provide clean and safer working place, improved the environmental performance, and reduction in construction time and labour requirements. Unfortunately, because of the higher initial cost that incur during the construction process, there is a significant percentage of construction projects do not adopt the use of off-site construction techniques in Malaysia. Hence, it is important for local authority to force a regulation regarding the application of off-site techniques in construction projects. This practice not only able to reduce construction waste generation at site, but also will lessen the burdens related with its management and disposal.

Next, the third practice for on-site waste minimization is C1, by providing waste skips for specific materials (waste segregation). In ‘Construction Method (on-site practice)” group, about 13 of 20 researchers stated this practice is able to reduce waste generated at site. In order to reduce total waste generated, there is a need for effective separation of waste, by providing waste skips for specific materials. This approach is based on the understandings that recycling construction material is one of the best option to reduce negative impact on the environment which also includes in 3R concept of waste minimization. Although waste segregation itself is not a strategy for waste reduction, but it is a requisite act to ease the construction materials reuse and recycling. This practice is applied as a method to facilitate construction waste for the recycling purpose after the waste generated in construction site. It is because, the application of construction waste recycling requires sorting of generated waste into “recyclables and non-recyclables” during the construction activities or at the recycling site. This practice will ease recycling operations and ensures accurate separation of inert and non-inert materials. By providing waste skips for waste segregation, there is likelihood of on-site reuse of the materials in waste skips or for other projects [23]. This practice also contributes in preventing waste mixture with soil [20].
As such, waste segregation provides both short and long-term benefits of on-site materials reuse and ease of waste recycling.

The highest frequency for the practice in ‘Administrative’ management group is the standardization of design and material. Standardization is defined as the extensive use of components, methods or processes in which there is regularity, repetition and a background of successful practice. The aim of this practice is mainly to improve the buildability of a structure along with the benefit in reducing construction waste. This study found that 12 out of 20 literature review had stated this practice is able to minimize on-site waste generation. Standardisation has the potential to dramatically reduce the current production of construction waste. This argument is supported by [22] that a substantial reduction in off-cuts construction materials could be achieved by designing room areas and ceiling heights in multiples of standard material sizes. Nowadays, the increase in complexity of a structure had caused a lot of design changes in construction projects. This situation raised due to the increased integration of components making it more likely that a change in one area of the design will require other areas to be redesigned [29]. This issue will directly contribute towards the generation of construction waste at site. Hence, administrative management play a vital role in the implementation of standardize practice for design and material in order to increase the buildability of a structure. This practice at once will contribute efficiently in reducing on-site construction waste.

Based on the ‘Material and Equipment’ management group, the study found that the highest frequency of on-site waste minimization is the proper material handling. There are 8 journals out of the 20 review journals stated that the proper material handling practice could reduce waste production. Generally, improper handling of construction material is one of the causes waste generation in construction project. This issue often arises because of the wrong material handling by construction workers at site which contribute towards waste production [19]. The incompetent supervisor and project manager, lead to poor workmanships and improper material handling done by construction workers. Besides that, the use of improper equipment in handling of material will cause damage and loss on the construction materials, subsequently will contribute to waste generation at site. In order to overcome this problem, it is important to use the right piece of handling equipment which aiming to prevent waste due to breakage and loss on the construction materials. In addition, the wrong materials handling by construction workers can be overcome by assigning a good and dedication supervisor at the site.

Table 2 presented the most significant practices in reducing on-site construction waste for each management groups. These factors are prominently able to engender on-site waste reduction in construction project.

![Figure 2. Frequency for the highest practices in each group based on the given code.](image-url)
Table 1. Construction management practices in reducing on-site construction waste.

| Group                     | On-site Waste minimization practices | Code | References | Freq |
|---------------------------|-------------------------------------|------|------------|------|
| **(A1) Human Resources**  | Improved education/awareness regarding on-site waste management of workforce or/and staff | A1   | [21] [22] [11] [23] [24] [25] [26] [27] [28] [29] [30] [16] [20] [33] [34] [35] [36] [37] | 18   |
|                           | Appointment of waste manager on-site | A2   | [413] [455] [504] | 3    |
|                           | Appointment of labors solely for waste disposal | A3   | [413] [455] [504] | 2    |
|                           | Preventing of waste materials by labors | A4   | [413] [455] [504] | 2    |
| **(B1) Material and Equipment** | Using mechanical handling to reduce damage on the material during delivery (proper handling) | B1   | [214] [228] [342] [356] [370] [384] [399] [413] [441] [455] [504] | 8    |
|                           | Prevention of over ordering of material | B4   | [214] [228] [342] [356] [370] [384] [399] [413] [441] [455] [504] | 7    |
|                           | Proper selection of materials (e.g. avoiding fragile material being used) | B2   | [214] [228] [342] [356] [370] [384] [399] [413] [441] [455] [504] | 7    |
|                           | Use materials with a high content of recycled material | B3   | [214] [228] [342] [356] [370] [384] [399] [413] [441] [455] [504] | 6    |
|                           | Prevention of double handling materials | B5   | [214] [228] [342] [356] [370] [384] [399] [413] [441] [455] [504] | 5    |
|                           | Buy materials avoiding unnecessary packaging | B6   | [214] [228] [342] [356] [370] [384] [399] [413] [441] [455] [504] | 4    |
|                           | Just in Time Deliveries (JIT) ensure less material waste | B7   | [214] [228] [342] [356] [370] [384] [399] [413] [441] [455] [504] | 4    |
|                           | On-site materials shredders or compactors machine | B8   | [214] [228] [342] [356] [370] [384] [399] [413] [441] [455] [504] | 4    |
|                           | Store construction materials collectively in a separate area | B9   | [214] [228] [342] [356] [370] [384] [399] [413] [441] [455] [504] | 3    |
| **(C1) Construction Method on-site** | Provision of waste skips for specific materials (waste segregation) | C1   | [214] [228] [342] [356] [370] [384] [399] [413] [441] [455] [504] | 13   |
|                           | On-site reuse construction materials | C2   | [214] [228] [342] [356] [370] [384] [399] [413] [441] [455] [504] | 12   |
|                           | Provide adequate and safe storage to lessen the amount of damaged material on-site. | C3   | [214] [228] [342] [356] [370] [384] [399] [413] [441] [455] [504] | 7    |
| Set-up an effective line of communication at construction site to avoid bad practice | C4 | * | * | * | * | * | * | 7 |
| Provide sufficient space to ease the management of C&D waste | C5 | * | * | * | * | * | 5 |
| Providing bins for collecting wastes for each subcontractor | C6 | * | * | * | * | 4 |
| Setting up temporary bins at each building zone | C7 | * | * | * | 4 |
| Periodic check on the use of C&D waste containers | C8 | * | * | 3 |
| Soil remains to be used on the same site | C9 | * | * | * | 3 |
| Storing waste at an easily accessible area | C10 | * | * | * | 3 |
| Noticing staff to reuse recycle materials | C11 | * | * | * | 3 |
| Preventing waste mixture with soil | C12 | * | * | 3 |
| Detect the construction activities that can admit reusable materials from the construction | C13 | * | * | * | 3 |
| Follow the project drawings / design | C14 | * | * | 2 |
| Informing methods to deal with the rest of wastes after recycling | C15 | * | * | 2 |
| Keeping the site clean to minimize loss of material and waste generation | C16 | * | * | 2 |
| Time scale of project can ensure effective waste reduction on-site | C17 | * | 2 |
| Use of demolition and excavation materials for landscape | C18 | * | 1 |
| Central areas for cutting and storage | C19 | * | 1 |
| Standardization of design and material to improve buildability | D1 | * | * | * | * | * | * | * | 12 |
| Adequate supervision of waste management activities with clear instruction | D2 | * | * | * | * | * | * | 8 |
| Ensure fewer design changes during construction process | D3 | * | * | * | * | * | * | 8 |

Administrative
| Supply chain alliances with supplier and recycling companies | D4 | * | * | * | * | * | * | 7 |
| Waste auditing to monitor and record on-site waste management | D5 | * | * | * | * | * | * | 7 |
| Making subcontractors responsible for waste disposal (cooperation) | D6 | * | * | * | * | * | 6 |
| Contract suppliers managing their product waste | D7 | * | * | * | * | * | 6 |
| Plan layout of construction projects properly (site planning) | D8 | * | * | * | * | * | 6 |
| Designing out waste will reduce material management issues on-site. | D9 | * | * | * | 4 |
| Recycling target to be set for every project phases | D10 | * | * | * | 4 |
| Involvement of contractors and product manufacturer during design stage | D11 | * | * | * | 3 |
| Positive incentive for decreasing or recycling by contractors/subcontractors | D12 | * | * | 3 |
| Rules on dealing with waste-generators | D13 | * | * | 2 |
| Shortening a period of collecting waste in a site | D14 | * | * | 2 |
| Design management to prevent the over specification of materials | D15 | * | * | 2 |
| Corrective actions to reduce waste when a change has happened | D16 | * | 1 |
| Adequate planning to stabilize work process on-site | D17 | * | 1 |
| Usage of offsite products and component (low waste construction technology) | E1 | * | * | * | * | * | * | * | * | * | 16 |
| The use of a Site Waste Management Plan (SWMP) is important. | E2 | * | * | * | * | * | * | * | 12 |
| Contractual clauses to penalize poor waste performance | E3 | * | * | * | * | * | * | 6 |
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Table 2. The highest frequency of on-site waste minimization practices based on management groups.

| Management group   | On-site waste minimization practices                                                      |
|--------------------|------------------------------------------------------------------------------------------------|
| Human Resources    | Improved education/ awareness regarding on-site waste management of workforce or/and staff |
| Material and Equipment | Using mechanical handling to reduce damage on the material during delivery (proper handling) |
| Construction Method | Provision of waste skips for specific materials (waste segregation)                           |
| Administrative     | Standardisation of design and material to improve buildability                               |
| Regulation         | Usage of offsite products and component (low waste construction technology)                  |

5. Conclusion
This study has been carried out with the aim to identify construction management practices which will engender the minimization of on-site construction wastes. As much as 20 research papers had been reviewed and the result of most significant practices for each management group has been clarified through mapping method. This study found that improving awareness and education of workforces regarding construction waste management is very important to achieve on-site waste minimization. In addition, the practices of the usage offsite products and component (low waste construction technology), provision of waste skips for specific materials (waste segregation), standardization of design and material, and proper handling of construction materials also important in order to encourage on-site construction waste reduction. This study provided soft measures that could be applied in construction site management practices, irrespective of the construction techniques.

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