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Best Practice of Construction Waste Management and Minimization

Material management is an important issue as seen in construction waste management. Best practice of material management is accompanied by various benefits which are acknowledged by several studies. The site layout has particular effects on both materials and their waste through effective waste management practice. Ignoring the benefits of material management could result in a daily reduction in productivity of up to 40% by material wastage. Thus, the benefits of effective material management must be well comprehended for the sake of waste minimization. Another convincing fact about waste is that poor site management accounts for the largest factor of waste generation. Hence the site condition is very crucial in developing effective material management. Factors contributing to the efficiency of material management process are effective logistical management and supply chain management. The logistics system must be performing as schedule so that materials are wisely managed on-site without encountering presence of excessive materials. As materials management is closely related to logistics in construction projects, there will be delay in construction projects when materials are not delivered to site as scheduled. The management must be effective in terms of delivery, off-loading, storage, handling, on-site transportation and on-site utilization of materials.

Keywords: *sustainable practice, prefabrication, construction, waste, management, building material, waste control, IBS*

1. Introduction

It should be pointed out that waste management is a crucial part in construction industry. In contrary to waste control, waste management involves the investment and development in new technology, products, processes and training that can reduce waste. While waste control is deemed to only a short term

period, waste management is preferred for its potential of becoming a revenue generator [1]. Eliminated of waste in terms of inventory scrap and electricity is suggested by the researcher by reducing the material, cost and waste. The researcher proclaimed that even small improvements such as reduce a little bit cost will have dramatic impact on the bottom line or final profit [2].

The failure of material storage system can also be devoted by the location of storage. Unsuitable storage locations are a big issue in poor labor productivity. Spatial arrangement in construction sites is precious as the space available is limited. Material storage shall be allocated at a place with least disturbance to the progress of the erecting process while providing ease of reach to workers needing them [3]. Once the material storage is assigned at a suitable place, transferring of storage location is not needed and hence leads to an increased productivity. Spatial congestion arising from mismanagement will affect the effectiveness of material storage system apart from resulting in diminished productivity levels.

2. Sustainable Practice

Since the increasing attention paid to Industrialized Building Systems (IBS), the government is keeping an eye on promoting and encouraging IBS to be an alternative to the conventional, labor intensive and wasteful method of construction. The Construction Industry Development Board of Malaysia (CIDB) provided "Industrialised Building Systems (IBS) Roadmap 2003 – 2010" and "IBS Roadmap 2011 – 2015" as a roadmap. According to the earlier roadmap, IBS integrates techniques, products, components or building systems with prefabricated components and on-site installation. The precast elements involved are in-filled walls, floor slabs, staircases and bathrooms into place to incorporation into the main units [4]. The duration of a project can be minimized by precast building systems provided certain conditions are met. As contrary to IBS, the conventional construction method utilizes the cast in-situ of wall, roof, column and beam using timber formwork. Steel, the other most important trade in conventional construction, is fabricated on site as reinforcement with varying sizes. This method of construction is regarded as labor intensive as it encompasses three separate trades which are formwork fabrication, steel bending, and concreting [5].

The widespread of prefabrication and IBS is expecting to be important means of reducing waste. Concrete and aggregate, soil and sand and brick and blocks are the largest components of waste materials and this finding is consistent in several researches. However, the proportion differs among the components. A huge difference is found between total waste generated in conventional project and IBS or prefabricated project and this finding is proven consistent in several studies. As an effort to reduce material waste, the largest components of waste appear to have highest frequency of reusing and recycling [6]. It is a good phenomenon that concrete and aggregate, soil and sand, wood and brick and blocks are reused and recycled most. Besides minimizing waste generation, the ascertainment of

prefabricated building components can raise the environmental performance for overall site conditions.

The adoption of prefabrication in Malaysia is still in developing stage. Starting from the completion of the Tunku Abdul Rahman Public Housing Estate or the Pekeliling Flats, to the adoption of 5-M strategy (manpower, materials-components-machines, management-recesses-methods, monetary and marketing), to the call for alternative construction material and technology under the IBS and designs in the Ninth Malaysia Plan, construction industry in Malaysia is gaining awareness on the importance and benefits of prefabrication in the industry. As a pioneer in leading the trend of prefabrication, the government implements minimum percentage of IBS requirement in government building projects. Apart from precast concrete, other prefabricated materials have entered the market including wood wool, gypsum, polymer, fiberglass, glass and aluminium-based IBS components [7]. Adding to the variety in the industry are at least 21 manufacturers and suppliers of IBS are readily promoting their systems in Malaysia. Despite the growing market in Malaysia, the ability of IBS to mitigate issues faced by the local industry players would undoubtedly exert a major impact on the industry in a few aspects including quality, productivity, health and safety, and the environment. In the construction sector, IBS is highly regarded as a solution to a few local issues such as construction time and industry's dependency on foreign workers. As though waste materials experience high rates in recycling and reusing, adoption of refabrication will bring down the quantity of waste in the generation stage not forgetting to counter with management problems [8].

3. Waste Minimization Practices

A thorough research is required in order to minimize the waste at an optimal level. Types, behavior, and production of waste must be studied well so that a practical and effective strategy will be proposed and opted. Construction projects are unique; each strategy applied must be modified to fit the characteristics of the projects. Contrary to the perception that waste is produced at construction stage, several researches show that production of waste is usual regardless of what stage in the construction project, be it design, construction and operation stage of the built facility [9]. In practice, the level of awareness of construction waste management is relatively low as seen from little measures taken against the issue. Waste minimization is often a low priority in the strategic planning of projects. The issue is discussed on how to manage the waste that has been produced rather than reducing the production in the first place. However, the chances of minimizing waste are reduced when the strategies are not discussed and practiced in the design or inception stage. Hence, the remaining strategies are only focus to the reactive minimization measures to control the existing waste.

Theoretically, all participants in a construction project have responsibility in minimizing construction waste. Hence, the attitudes of key individuals engaged

with the project have high influence on the waste levels. The project flow which involves client, consultants, builders and suppliers shows that each individual plays an important role in each stage to coordinate with each other and minimize waste as a whole. Starting from client which initiates a project, the client has great influence on the overall waste level as seen from many perspective. Generally, environmental standards and budget determined by the client would shape the level that the project team must comply. This would greatly determine the level of effort the project team is going to put as the client has the ultimate higher decision making despite the advice given. However, construction projects are the output of a team which comprises of different professionals and roles. If the supply chain does not follow the requirements set, the hard work of minimizing waste practices will not be paid off. Despite the teamwork in any construction projects, it is seemingly more important to pay more attention to supply chain management in order to curb the problems of waste.

Waste can be minimized at the design stage where the designs are uniform and consistent. In practice, standardization of design is adopted to improve buildability and reduce the quantity of off-cuts. Consistent design throughout an area of the building will ease the fabrication process. Designs will be prepared and fabricated in large quantity in repetition without allocating extra time and effort for off-cuts and specification. Standardization is a more preferable alternative in design as it is proven to significantly reduce the current production of construction waste [10]. Architectural works and structural works with standardization in design will help to lower the cost while reducing waste.

Poor site management is always regarded the main cause of waste generation. Despite the parties who are responsible for effective site management, some improvement in the supply chain will help to reduce the severity of the issue. Recycling companies and suppliers alliance with the supply chain is an alternative to minimizing waste. A well comprehensive supply chain consisting of appropriate recycling suppliers can effectively help to manage the waste from the site. With such resources, excess materials will be removed effectively before the excess materials turn out to be unusable. Excess materials or leftovers are also possible to be converted into new product for other use. Recycling materials are commonly found and used in construction projects for same level of performance with lower cost. Recycling materials are the outcome of reuse, reduce and recycle effort in minimizing waste. Such approach of waste minimization is often supported with financial incentives from related bodies [11].

Site management can be improved in the aspects of waste classification. As the stage proceeds during construction projects, different types of building materials will be produced. It is foreseeable and predictable that certain materials will be the domain waste during different stages. Hence, provision of waste skips for specific materials is a good practice of minimizing waste. For instance, foreseeable materials in the finishing stage of the building are tiles, packaging and wires. Materials like timber, bricks, steel bars and debris are less likely to be found

during the stage but their existence too cannot be denied. Central controlling of skips for materials is the principle in classification of waste on site. It helps improve segregation and recycling in the later stage. Another benefit of providing waste skips is the materials can be handled with lesser effort which in turn enhances productivity. The excess materials can be contracted out to specialized suppliers according to the types. The site management team is able to clearly manage the waste according to the major waste collected. Apart from it, the contractor is able to exercise their rights over removal of waste and recovering costs through recycling by retaining responsibility for waste management.

Lean construction or just-in-time delivery strategy is one of the approaches which are highly recommended for countering the issue. This approach is different from the conventional way of material storage as the time that materials were stored on site is reduced. This relatively reduces the potential that the materials experience damage resulting from poor handling. The materials are ordered and delivered in a precise quantity and in nearest proximity to the commencement of the work. Hence, lesser extra materials are ready on site. Lean construction also prevents damage to the materials due to weather site limitation. Long-term site storage is prevented as materials will not be stored for a long time until they are utilized in the project [12]. This strategy oversees a strong and well-coordinated relationship between contractor and supplier the ordering of materials must be made precisely considering the time taken for delivery process. Not only good communication is crucial, the estimator or contractor will need to justify on the quantity to be ordered and being able to foresee the criticality for ordering materials is an add-on in managing the project. By practicing suitable estimation and ordering of materials, over-ordering can be prevented in the first place.

Another strategy in relevance to site management is to engage dedicated specialist sub-contract package for on-site waste management in construction projects. Specialists in waste management engaged with the project are responsible in providing solutions to the waste collected on site. Justification will be made on common waste such as timber, metal and organic materials for reuse. These materials will be contracted out of the site and managed by the specialists for individual solutions. Each type of waste will be treated differently with the same idea; to raise the usability of resources. Being a form of valuable resources, most common wastes are in high demand for other usage with reprocessing. The responsibility of reusing the materials falls onto the contractor which does not involve these specialist sub-contractors. The main contractor remains responsible for control over waste processes. The specialists are responsible for delivering and managing the waste for further use, if possible. The outcome is seen from the reduced amount of waste sent to landfill.

As site management is highly coordinated with contracts, contractual clauses are able to help control waste by penalizing poor waste performance. Contractual clauses play an important role in ensuring waste production is as minimal as possible. This is due to the fact that site management must always follow the

regulations in the contract as agreed so that obligations of contractors are performed in a required state. Acknowledging the influence of contract, some rules and regulations as the effort to minimize waste can be incorporated to the contract so that contractor abides to the agreement. Hence, client's idea on minimizing waste must be well understood while outlining base for contract. Mostly, money is a big concern in construction projects and the clauses can be drafted in a way that financial penalties to be imposed for wasteful work practices. Financial penalties can work as a good guide so that the contractor fully abides to the contractual clauses. In some cases, only a certain percentage of wastage is allowed during a trade and the waste beyond the allowance should be borne by the traders. This concept is a good application of transferring the responsibility to the third party. Risks and deficiency will be transferred and shared to a third party. Resulting from this act, it will raise the awareness of waste minimization among the sub-contractors or suppliers. Contractual clauses will enable monthly data collection on waste disposal from the sub-contractors or suppliers so that analysis on the data can be carried out to implement precaution steps in the future [13].

In the design stage, design management is important to ensure the over specification of materials are minimal. The client's perception on the design must be well understood and comprehended to the design team so that an agreement will be achieved in not sacrificing aesthetic values and total costs. Design consultants should aware of the design specification so that design management is able to control the design stage as a whole in order to achieve financial savings. Apart from exceeding budgeted costs, over specification will induce more waste in the fabrication process. Hence, the design team is expected to deliver the concept of minimal over specification so that client's requirements are met in a harmonious way.

Additional tender premiums allocated will help the team to achieve waste minimization where waste initiatives are to be implemented. Allocation of cost on waste minimization should be included in the initiation stage as initial cost so that the effort could be carried out with ease. At times waste management requires provisions of experts and hence the decision of waste reduction must be determined during the early stage so that appropriate budget is allocated for the later stage. Strategies should be focused on adverting barriers into helpful aids. Generally less composition of initial costs is allocated for minimization strategies as more corporates are keen in spending the budget in other aspects rather than waste. If financial subsidies were provided as an incentive, the corporates will be more dedicated and initiated to make arrangement for waste related issues. Government or regulatory bodies giving incentives or rewards for minimizing waste are appreciated by the industry for acknowledging the effort paid.

One useful effort made is waste auditing to monitor and record environmental performance on-site. Collection of information from the ongoing projects and past projects are capable of giving critical analysis of waste management strategies in the future. By collecting data, workforce can be educated on the importance of

minimizing waste as well as to monitor the performance of the system applied. Since construction projects are unique from each other, some strategies may not be fully compatible to one project. A thorough observation and analysis on the performance is able to determine the suitability of the method and the further actions be taken for next similar projects. Pros and cons of the method will be recorded for future references.

On site controlling and monitoring, fabrication of specification on site will largely produce waste of materials due to several factors. Hence, the increased use of prefabrication is effective in reducing waste produced on site. Off-site prefabrication guarantees a higher quality of product compared to on-site fabrication as the conditions and surroundings are more controlled. Resulting from that, errors in fabrication will be reduced and avoided thus reduces the amount of on-site damage, reduce re-work and waste. External factors such as site conditions and weather conditions often bring huge impact to the fabrication and thus the fabrication becomes more vulnerable to such parameters. Careful modularization of the building design helps to reduce the risk of damaged mould and hence increasing efficiency of materials [14].

As suggested by previous researcher, site management is the most significant factor to induce construction waste. In order to contribute to a better environment in construction industry, the management to the waste skips is crucial as they provide the proper allocation of waste on the site without creating more mess to the site condition. However, it is found that skips actually comprise large volume of air voids; as high as 50-70 percent of air voids is found in a full skip. The introduction of on-site materials compactors is one solution to more efficiently manage the waste skips. Indirectly, increasing space in the waste skips will help succeeding the minimization of waste by reducing transportation costs to deliver waste. Although the same volume of waste exists after the waste skips are compacted, the extra space created will allow for longer time of waste collection on site. Acknowledging the benefits of materials compactors, however, this method is not applicable for all cases and every type of materials. Certain materials are not suitable for compaction such as metal bars and timber. Also, on-site materials compactors are preferable for materials to be sent to landfill. Since most of the waste materials from site could have undergone reprocessing for further use, the method is likely applicable to most cases.

The attitude and awareness of stakeholders on waste minimization is highly a factor to the success of waste minimization. At times when the awareness within the client is scarce, the initiation to opt for measures to minimize waste will get lesser. This is an unhealthy situation found in the construction industry as many clients are unaware of the potential for the reuse of recycling of materials. Educating clients about measure to reduce waste levels is favorable as studies showed that most clients possess low awareness on severity of construction waste. Conventionally, clients are more concern on the budget and outcome of the project. Importance of managing and minimizing waste is often neglected by many

participants including the client. Clients are unaware of the environmental impact these waste could bring in deterring the effort to achieve sustainability. Realizing the low awareness among the clients, regulatory bodies could introduce education programs which are related to the global issues as well as to suit the localities. Information conveyed should spindle around increasing awareness of minimizing waste and introducing related measures for waste conscious design and construction practices. Through such educating programs, the clients will be able to grasp the idea of the contributions they are capable of contributing for a sustainable environment as a stakeholder [15].

As the supply chain plays an important role in minimizing waste, flexibility in supplier to provide smaller quantities of materials could lessen the burden in site management. As construction projects are unique and different from each other, quantities of certain materials differ vastly across projects. Some materials are required in different quantities as stage proceeds. Hence, precise quantity of materials provided will deliver the help in minimizing waste on site as excess materials are not present. This results in reducing the needs for on-site storage and the opportunities for damage to occur on-site. Materials supplied in precise quantity will be used up for the allocated time and erection phase there is lesser risk for materials to become void. Supplier engaged with the project team shall understand the intention to prevent excess material wastage and thus come out with a win-win solution for both the parties without harming each other's interests. Studies have shown considerable savings are achieved when suppliers provide materials in flexible amount out of supplier flexibility is in integral to waste minimization. However, suppliers generally are unable to meet such flexibility from the aspects of costs. Suppliers prefer materials ordered in a large bulk to enhance cash flow of their business and to increase business opportunities. Hence, appropriate communication between both parties is important to deliver the right message so that minimization of waste is practiced all across the project phase.

Intention stems from the concern toward environmental sustainability is a great initiation to encourage waste minimization. Often, the construction projects are examined to comply with environmental assessment. Environmental impact assessments on the buildings are often carried out during the design phase. This will prevent and guide the design to output lesser impact to the environment. While reviewing the design and production, waste minimization strategies incorporated during the stage is also studied so that the strategies comply with the design and environmental sustainability [16]. Environmental impact assessment should be part of the design process as a decision making support tool. The data analyzed from the assessment should be put into good use for the building. Other equally important parameters in influencing the decision making are cost and functional requirements of the building to the occupants or owner. A balance between the three parameters can be achieved provided a brainstorming during the assessment in the early stages including the design phase. Environmental impact, particularly energy consumption, is the main issue in the current trend as the resources used

are facing scarcity along the time. The regular design reviews have become a norm in the design development process to ensure the building meets the client's specification.

4. Obstacles in Waste Management

The call for awareness in construction waste minimization is not insignificant however there are obstacles that prohibit the smooth execution of waste mitigation strategies due to some unavoidable factors. Despite recycling of waste materials is a highly encouraged alternative to traditional landfilling and incineration, the difficulties in recycling the construction waste hinder the smooth operation of recycling. High level of contamination and large degree of heterogeneity in the building materials waste complicate the recycling process. As waste materials are not taken care of before disposing, it appears that the building materials waste contain high level of contamination. The insufficient space for disposal in large cities alerts the issue to be the focus at national level. The ignorance in the consequences of construction waste has resulted in increasing need for landfill area. If the issue is well taken care of, the quantity of waste being sent to landfill will decrease gradually. Accompanying this will be the reduction of pollutions to the environment including the emission and residues from incinerators for waste disposal [17].

If the condition persists, high level of waste in the industry will lead to depressing future availability of the materials and energy and creation of unnecessary demand in transportation. Construction industry consumes a large amount of resources and energy in the process, the resulting impact on the scarcity of resources is immediate. In China, construction industry consumes 40% of total natural resources and 40% of available energy. The depletion in nonrenewable resources such as timber, sand and crushed stone is mainly due to the vast development in construction industry.

Another hindrance act to minimization of construction waste is the perception towards construction waste. Practitioners in construction industry probably do not possess quality understanding in the matter and often mistake construction waste the debris removed from the site and disposed of in landfills. Resulting from the misconception of waste, other possible causes of generating waste are not paid attention to. In other words, this ceases the implementation of prohibitive acts in order to advocate sustainability. The common practice has echoed with previous research that the priority given to waste management is relatively low [18]. The consequences of the lack in awareness have resulted in many cases of waste during the various stages in construction project. For example, design deficiency where the designers did not apply the concept of waste minimization in choosing building materials is always a norm in construction waste. Design management is an important sector to be taken into consideration where over specification tends to enhance the production of waste. As the main

practitioner in cost controlling, the employer generally does not allocate resources in waste management as their concern does not fall on reducing environmental impact. Hence, in many cases, the client focus on the progress of works than waste management and does not expect waste management to be done [19].

Closely related to awareness, the ability and knowledge in operatives highly affect the execution of construction waste minimization. The lack of skills in operators will result in poor waste control. A well trained operator as compared to semi-skilled worker will perform better in daily productivity. Workmanship is highly regarded as most critically responsible for its outcome. The overview in workmanship allocation must be done in every stage of construction as waste may be produced at any stage of the process, regardless of design stage, construction stage or operation stage. The operatives often lack of knowledge on the impact to the environmental sustainability which is potentially brought about by not minimizing waste.

Apart from that, the maturity level of recycling market prohibits the growth of construction waste minimization. A well-developed supply chain and reverse logistics is critical in providing means of managing physical waste from construction sites. Particularly in recycling, the market does not provide a sufficient platform for the receiving the recycled product. The non-collaboration between important parties decreases recycling rates. If the need for supply chain for waste recycling market is thoroughly studied, it will become an important measure to effectively reduce the waste by removing the waste from site. The establishment of supply chain alliances with recycling companies serves as a right channel to remove, reprocess and reuse the excess waste. The handling of waste as it leaves the site must be planned well with the intention of recycling to curb the many problems arising from construction waste generation.

The insufficiency in regulations is regarded one of the obstacles in waste minimization. The government plays an important role in overlooking the progress of construction waste management considering the environmental impact brought about by poor management of construction waste. However the government's inaction to enforce laws on waste management has caused stagnant in practicing waste minimization. In Hong Kong, the legal measures taken are ineffective in implementing environmental management. It can be seen that the usage of recycled products is optional and the act of pursuing recycled materials in construction projects is not rewarded in return. In practice, the lack of Kuwait Municipality in persuading the use of recycled products made becomes one of the obstacles in waste minimization [20].

The less attention given to construction waste management indicates a low level of financial incentives allocated. As waste management is often regarded falls out of cost efficiency, the employer perceives that the need of minimizing waste as out of their obligations [21]. Lack of incentives and penalties demotivates the construction practitioner to look up to more practical solutions. Almost both are perceived to have similar effect, incentives are preferable over penalties in waste

reduction. The reward system is best practiced through the construction process as a short and intensified measure such as during the design process as it will act like key incentive in boosting performance.

5. Conclusions

The widespread of prefabrication and IBS is expected to be important means of reducing waste. Concrete and aggregate, soil and sand and brick and blocks are the largest components of waste materials and this finding is consistent in several researches. However, the proportion differs among the components. A huge difference is found between total waste generated in conventional project and IBS or prefabricated project and this finding is proven consistent in several studies. As an effort to reduce material waste, the largest components of waste appear to have highest frequency of reusing and recycling. It is a good phenomenon that concrete and aggregate, soil and sand, wood and brick and blocks are reused and recycled most. Besides minimizing waste generation, the ascertainment of prefabricated building components can raise the environmental performance for overall site conditions.

All participants in a construction project have responsibility in minimizing construction waste. Therefore, the attitudes of key individuals engaged with the project have high influence on the waste levels. The project flow which involves client, consultants, builders and suppliers shows that each individual plays an important role in each stage to coordinate with each other and minimize waste as a whole. Starting from client which initiates a project, the client has great influence on the overall waste level as seen from many perspective. Generally, environmental standards and budget determined by the client would shape the level that the project team must comply. This would greatly determine the level of effort the project team is going to put as the client has the ultimate higher decision making despite the advice given. However, construction projects are the output of a team which comprises of different professionals and roles. If the supply chain does not follow the requirements set, the hard work of minimizing waste practices will not be paid off.

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