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Theoretical Framework for Sustainable Construction Waste Management in Penang, Malaysia

[1]Seow Ta Wee, [2]Ng Lee Shan, [3]Tan Lai Wai and [4]Goh Kai Chen

[1]Associate Professor, Department of Construction Management, Faculty of Technology Management and Business, University Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu pahat, Johor, Malaysia.
[2]Phd Student, Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu pahat, Johor, Malaysia.
[3]Associate Professor, Department of Water and Environmental Engineering, Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu pahat, Johor, Malaysia.
[4]Senior Lecturer, Department of Construction Management, Faculty of Technology Management and Business, University Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu pahat, Johor, Malaysia.

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ABSTRACT

Background: Rapidly development in the construction industry has led a large amount of construction waste generated. It is also increasing the quantity of waste disposal at landfill. Weaknesses of implementation of construction waste reduction through 3R (Reduce, Reuse, Recycle) among contractors will caused to non-sustainable construction waste management. Currently, there are only two landfills operating in Penang, Malaysia. These both landfills are unable to accommodate the amount of waste disposed in the long term. In addition, Penang is an island area and land is scarce to build new landfills. Besides that, construction waste can lead to negative impact of environmental, human, health of human, and dissipation of natural resources. Contractor should manage construction waste through 3R as it is sustainable practice. **Objective:** This paper aimed to study the current practice of construction waste reduction through 3R among contractors; to discuss constraints of implementation construction waste reduction through 3R in Penang, Malaysia; and to analyze the effective elements to improve the implementation of construction waste reduction through 3R. **Conclusion:** Reduction of construction waste through 3R is one of the approaches towards sustainable construction waste management. Therefore, all the parties involved in construction waste management should play role to emphasize and focus construction waste reduction through 3R among contractor.

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INTRODUCTION

Waste defined as all items that people no longer have any use which get rid of or have already discarded. But, waste can also be resource if it is put in the right location (Ngoc and Schnitzer, 2009). Construction waste is defined as waste that is generated from the construction industry during construction activities, building renovation, civil construction and building, construction site cleaning, road construction and demolition activities, including soil excavation (Shen *et al.*, 2004). Such as dirt, brick, concrete, asphalt, glass, plastic, metal (Huang et al., 2011), wood, raw or semi-processed wood, drywall and masonry (Agamuthu, 2008). Waste management is processes which include site planning, transport, storage, handling, operation on site, segregation, reuse, recycling and disposal (Osmani, 2011).

Solid waste reduction through 3R is one of the thrusts of National Solid Waste Management Policy. 3R represents the concept of reduce, reuse and recycle (NSWM Department, 2012). Controlled solid waste include commercial solid waste, construction solid waste, household solid waste, industrial solid waste, institutional solid waste, imported solid waste, public solid waste and time to time solid waste (NSWM Department, 2013).

The 3R approach is often used in research and practices on construction waste management in order to such effects of generated construction waste.

The 3R approach refers to the reduction, reuse, and recycling, which is a three classification of waste management strategies (Yuan et al., 2011). It defined as **(i) Reduction:** it is considered as the most effective and efficient method to manage construction waste. Reduction does not only reduce construction waste generation, it also can reduce the

Corresponding Author: Ng Lee Shan, Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia.
Tel: +60165532456; E-mail: leeshan3122@gmail.com

cost for transportation, waste disposal and waste recycling (Poon, 2007; Esin and Cosgun, 2007). Reduction of construction waste through 3R is one of the methods towards sustainable construction waste management (Ngoc and Schnitzer, 2009). **(ii) Reuse:** The method of reuse is usually a favorite option because some construction waste can be reused in other construction project. Reuse is the most beneficial and contractors can save money compared to the disposal cost charged (Winkler, 2010). **(iii) Recycling:** The method of recycling construction waste can be categorized into two, which are on-site recycling and off-site recycling. On-site recycling is defined as the segregation of the construction waste for subsequent use as the raw materials in the construction project. Meanwhile, off-site recycling is the segregation of the construction waste which are then transported to other organizations or locations and the waste is used as raw materials (Franchetti, 2009).

In the 3R approach, waste resources will be fully utilized before it is sent to disposal. The 3R approach is a popular option among the other alternative of the waste hierarchy concept and increasingly included in the policy (Hezri, 2010). Improvements to construction waste reduction has been emphasized in order to achieve the goal of sustainable industry (Kulatunga et al., 2006). The construction waste management in Malaysia is very important in effort to develop sustainable in the future (Nagapan et al., 2012).

Construction and demolition waste is a major problem which it accounts 25% to 30% of all the types of solid waste generated every year (Rodríguez et al., 2015). Recyclable materials at most 70% to 80% of the total waste composition as found placed in the landfills in Malaysia (Moh and Manaf, 2014). Most of solid wastes generated were disposed directly at landfills or disposal site (Saat, 2013). Landfills receive the brunt of un-recycled construction and demolition waste. The construction and demolition waste management challenges that arise from its high volume and density are compounded by its generally larger size, lack of malleability and the hazardous nature of the airborne particles associated with it (Agamuthu, 2008).

The effectiveness of the implementation of construction waste reduction through 3R reflects the sustainability in construction waste management. Weaknesses of implementation of construction waste reduction through 3R among contractors will caused to non-sustainable construction waste management. This will then lead to increase in the construction waste in landfills. This is critical especially on islands where land is very limited for solid waste disposal activities to be carried out. According to the Ministry of Urban Wellbeing, Housing and Local Government (UHLG) (2015), **Table 1** shows the report of UHLG selected statistics until March 2015 shows that currently there are only two operating landfill or solid waste disposal sites in Penang, Malaysia. This research focuses on construction waste reduction through 3R among contractors in Penang. Both of the landfills will be unable to accommodate the amount of waste disposed in the long term. In addition, Penang is an island area, and land is scarce to provide new landfills.

Theoretical Framework for Sustainable Construction Waste Management:

Theoretical framework is a concept associated with the study and as a guideline for conducting this research. Besides that, theoretical framework also describes the concept and approach explaining the phenomena of current implementation of construction waste reduction through 3R. The theoretical framework is presented as going through into two parts as shown in **Fig. 2**. The theoretical framework describes the weakness implementation of construction waste reduction through 3R among construction contractors bring negative impact and constraints. Thus, the current implementation of construction waste reduction through 3R among contractors needs to be improved in order to reach a goal of sustainable construction waste management.

The Government should enforce the policy through the implementation of top-down approach with adopting the important elements among the community and organization. In addition, good governing concept should implement and applied in all the important effective elements in order to achieve sustainable construction waste management among contractors. Effective implementation only can be achievable if there is existence of good governance in the important elements at different levels of stages. According to Kurian and Nagendran (2007), governance can identifies the blurring of boundaries and responsibilities to determinate the empowerment involved in the relationship between each other.

A framework encompassing the good governance concept is necessary in order to protect policy, conserve and improve the environment which can be developed and legislation is respected. Good governance requires that decisions are implemented within a clear and legitimate process to achieve consistent and effective policies. Good governance means the decisions are made which promote sustainable development which includes environmental protection when regarding with environmental resources (Harman, 2005). Application of good governance is necessary to achieve sound waste management and sustainable recycling industry (Atienza, 2011).

1.1 Weakness Implementation of Construction Waste Reduction through 3R among Contractors:

A large amount of construction waste produced by the construction sector due to the demands in implementing major infrastructure, commercial building and housing development projects in Malaysia (Begum et al., 2007b). The objective of the 3R program is to reduce the solid waste generation through reduce, reuse and recycle. This objective is in line with the National Recycling Target 22% of the total solid waste can be recycled by the year 2020

(Agamuthu et al., 2011). However, recycling is still at an infant stage in Malaysia (Manaf *et al*., 2009). Majority of contractors do not practice source separation, source reduction, reuse or recycling at construction sites (Begum et al., 2009). The currently recycling rate of Malaysia is only 5% Malaysia is putting effort in implementing sustainable disposal alternative of recycling. However, there is still a long way to improve and develop from the current situation (Moh and Manaf, 2014).

Table 1: Number of operating and terminated solid waste disposal site by State until 31 March 2015 (Ministry of Urban Wellbeing, Housing and Local Government, 2015).

State	Number of operating site	Number of terminated sites
Johor	14	23
Kedah	8	7
Kelantan	13	6
Malacca	2	5
Negeri Sembilan	7	11
Pahang	16	16
Perak	17	12
Perlis	1	1
Penang	2	1
Sabah	19	2
Sarawak	49	14
Selangor	8	14
Terengganu	8	12
WP. Kuala Lumpur/ Labuan/ Putrajaya	1	7
Total	165	131

Although promotion of 3R is suggested in construction for several years but the satisfactory environmental awareness seem cannot be achieved and the effectiveness of 3R applications seems limited (Tam, 2010). The implementation solid waste reduction through 3R is currently ineffective and has limited in the construction industry in Penang (Ng et al., 2015a). The sustainable resource and waste management is remains a low priority among majority of the contractors in Malaysia. The 3R practices are limited in the construction due to there is no mandatory requirement for construction companies to practice sustainable resource and waste management (Begum et al., 2009).

Besides that, due to the lack of proper data collection, the actual figures for worldwide waste generation are not available (Fauziah et al., 2004). Meanwhile, currently there was no systematic documentation and detailed data and information on the volume construction waste generated, type of waste, amount of raisings generated and disposed in Malaysia (Moh and Manaf, 2014; Begum et al., 2006). Data on waste minimization and recycling provided by local authorities is even more widely varied, not standardized, uniformity, and inconsistent in accuracy (Moh and Manaf, 2014). There are number of policies and voluntary initiatives to solve this issues and supporting sustainable resource and waste management in the Malaysian construction industry. However, the reality remains challenging in Malaysia (Papargyropoulou et al., 2011). Therefore, waste minimization is an important to concern and emphasize in the implementation of the construction waste management in the construction industry of Malaysia (Begum et al., 2007b).

1.2 Issue/ Impacts:

Rapid growth in construction activities increases construction waste problems around the world (Nagapan et al., 2011). The weakness of implementation of construction waste reduction through 3R caused some negative impact such as environmental problem, human health, and dissipation of natural resources. Therefore, Esin and Cosgun, (2007) mentioned that the priority should be given to improving waste management system in order to reduce the generation of construction waste.

- ***Environmental:***

Construction waste management has been promoted for the goal to protect the environment due to that wastes from construction works activities contributes significantly to the environment pollution (Shen et al., 2004). Construction waste become the serious environmental problems in many countries which large volumes of construction waste burdening the landfill capacities and also leads to environmental issues (Esin and Cosgun, 2007). The construction industry has a major impact on the environment and its environmental effects are directly relation to the quality of the waste generated (Begum et al., 2007a). The ingredients of construction waste may cause the environmental pollution after dumped or disposal in landfill site. Under the impact of the rain water, the leakage water mixed with the construction waste will pollute the surrounding groundwater, surface water and soil (Liu and Huang, 2013).

The environmental impact of the construction industry is substantial in developing countries because of the fact of developing countries are still under construction and increased a rapid urbanization and industrialization. Thus, its making the construction industry become one of the biggest factors impacting on the environmental. Therefore, construction industry in Malaysia plays a significant role in meeting the needs of its society and enhancing its quality of life (Begum and Pereira, 2011).

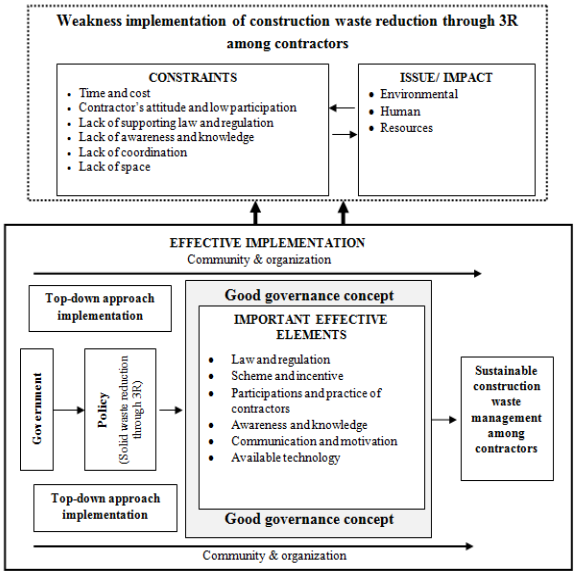

Fig. 1: Theoretical Framework of Construction Waste Reduction through 3R towards Sustainable Construction Waste Management in Malaysia.

- ***Human:***

Construction waste is not only a simple environmental problem, but it also has bringing negative impact on the health and hygiene (Wei and Rotter, 2008). Dumping on landfills may cause soil and groundwater pollution. Currently in Malaysia, traditional disposal method is creates the disturbances and imposing apprehensive and psychological fears of health and ecological risks (Chuen and Jamal, 2011).

- ***Resources:***

The expanding of construction waste shows a bulk dissipation of natural resources (Hu, 2011). Uncontrolled disposal of CDW into landfills is a practice of dire waste of finite natural resources (Agamuthu, 2008). Majority of contractors prefer to purchase new material is cheaper than recycling which disposal process is simpler than recycling (Shareh Musa et al., 2009). The 3R practice is an important aspect of an efficient and effective way help to reduce amount of waste going into landfills. It is also a way to decrease resource throughput (Shareh Musa et al., 2009; Ho, 2002).

1.3 Constraints:

Increased waste generation creates more problems which are not able to manage wastes due to institutional, financial, technical, regulatory, knowledge, public participation (Ngoc and Schnitzer, 2009), limited effectiveness of government legislations, and lack of joint efforts of all main practitioners involved (Wang et al., 2010). There are some constraints of implementation construction waste reduction through 3R had found from previous research been done such as time and cost, contractor's attitude and low participation, lack of supporting law and regulation, lack of awareness and knowledge, lack of coordination, and lack of space.

- ***Time and cost:***

Coffey (1999) pointed out that construction solid waste management is generally seen as a low priority when financial constraints are present. Most construction contractors only focus on short-term economic benefits and are unwilling to increase inputs on construction waste management (Hu, 2011). The reasons behind this lack of practice of waste management applications were found such as profit, time and cost (Kulatunga et al., 2006). On-site sorting needs substantial labor input which would increase the cost of construction project (Poon et al., 2001). The cost of processing recycled waste is higher than landfill cost which include the cost of the collection, sorting, and crushing. Besides that, recycled materials prices are higher than the original materials (Wei and Rotter, 2008).

- ***Contractor's attitude and low participation:***

Lack of public co-operation and participation is the problem of construction waste management (Shen and Tam, 2002). The behavior of construction workforce in the actual indicates a lack of effort to practice positive attitudes and perceptions to improve the waste minimization (Kulatunga et al., 2006). Some waste segregation is practiced unless it is specified in the contract (Xun et al., 2008) and with the aim to recycle materials with some value such as high scrap value recycling materials. While, other non-profitable wastes are mixed together without any processing either sent to landfill, burned or illegally buried on site (Papargyropoulou et al., 2011; Wei and Rotter, 2008; Hu, 2011). Therefore, contractors need to change their attitude in order to achieve goals

of reduce construction site waste (Hassan et al., 2012).

- ***Lack of supporting law and regulation:***

There still several challenges towards achieving sustainable construction waste management which is the lack of explicit legislature governing construction waste management. There is remains weak or ineffective legislation to govern and monitor the construction operations and practices in construction waste management (Agamuthu, 2008). The related regulations and legislations enforced by government are too liberal. Waste producer is failed to concern the environmental during implement the construction waste management if the enforcement is non-mandatory (Wei and Rotter, 2008). Existence of policies, laws and regulations governing 3R principles for construction waste waste is minimal in Asia recently. There are do not have specific regulations formulated for construction wastes in most of the countries (Nitavattananon and Borongan, 2008). Weak enforcement and ineffective policy implementation make the management of waste in developing countries very low possibility of improvement (Fauziah et al., 2004).

- ***Lack of awareness and knowledge:***

Many factors are contributing towards the failure of 3R implementation in most developing countries including Malaysia. The perception and awareness of recycling among the public is not high and low public concern is the caused the limited recycling implementation (Agamuthu et al., 2011). Lack of knowledge on construction waste management has a major constraint compared to other issues (Hassan et al., 2012). The problem of construction waste management is absence of waste recycling programs in most communities (Shen and Tam, 2002). Therefore, appropriate step should take towards increasing promotions for practicing 3R in construction waste management in order to deliver sustainable practices for the benefit of the society, economy and the environment (Papargyropoulou et al., 2011).

- ***Lack of coordination:***

Construction waste management strategies particularly the 3R requires coordination and cooperation with all the involvement of local, national and regional governments to oppression the issue of environmental and propose the solutions and strategies to address that problem (Nitavattananon and Borongan, 2008). That management will be difficulties due to lack of fruitful cooperation between the authorities (Fatta et al., 2003). Besides that, lack of coordination among the relevant agencies often results in different agencies becoming not being aware about what other national agencies are doing and different solid waste management. Thus, there are often blurring roles of the various national agencies defined in relation to solid waste management and also no committee designated to coordinate the projects and activities (Kurian and Nagendran, 2007).

- ***Lack of space:***

On-site waste sorting is an effective means to reduce the quantities of construction waste to be disposed of at landfills. However, it takes up much site space and requires a high level of management (Poon et al., 2001). Limited waste storage area on site ranked as the major barrier for implementing waste sorting, waste reduction should be considered at beginning of projects (Poon et al., 2013).

2.1 Important effective elements:

The important effective elements are law and regulation, scheme and incentive, participations and practice of contractors, awareness and knowledge, and available technology. Effective implementation only can be achievable if there is existence of good governance in the important elements at different levels of the stages.

- ***Law and regulation:***

Construction organizations normally only consider to meet the requirements that set in as the mandatory control measures. Contractors will not implement them if the requirements are not mandatory (Tam et al., 2007). Legislation can be used as appropriate approach to promote the benefits of waste management with the willingness and acceptance of participation by practitioners (Udawatta et al., 2015). A mandatory regulation requires in Japan in order to promote the use of recycled construction waste (Xun et al., 2008). Japan plays a leading role which shift from focus on mere attention to basic regulatory problem of 3R issues and goals within the country to internationalization (Hezri, 2010). The Singapore government prefers using the law and regulations to enforce the policies by adopting a top-down approach (Ho, 2002).

Therefore, Malaysian government should consider establish a series of effective laws and regulation on construction waste management which to create awareness among contractors (Papargyropoulou et al., 2011). Some regulations and standards regarding to quality for using recycled materials and pollution control also need be promulgated (Wei and Rotter, 2008). Recycling should add into the construction tender document (Li et al., 2011). Waste management plans and environmental protection should be evaluated in the process of evaluation of tender and consider as one of factors to successful bid (Hu, 2011).

- ***Scheme and incentive:***

The Hong Kong Government has implemented the Construction Disposal Waste Charging Scheme (CDWCS) in December 2005 (Poon et al., 2013) in

order to reduce waste and promote reuse and recycling construction waste before disposal which to levy charges on C&D waste disposal to landfills due to limited landfill space (Yu et al., 2013). According to government statistic show the average amount of construction waste disposed in landfills in Hong Kong was decreased by 40% in after a year implemented the CDWCS (EPD 2007).

Besides imposing high waste management fees, governments may also implement incentives to promote construction waste reduction (Poon, 2007). Usually, contractors will consider economic viability and they need incentives motivation (Udawatta et al., 2015). Establishment of waste allowances and incentives would help to improve its performance waste management in the construction industry (Kulatunga et al., 2006). The government should provide incentives due to contractors unwilling invest much on environmental management because it had increase in their operating costs (Tam et al., 2007). Promptly reward should be given to contractors those implement 3R practices to improve waste minimization. Thus, local authorities can use some positive (monetary) and negative rewarding (punishment) measure among constructors (Begum et al., 2007b).

- ***Participations and practice of contractors:***

Participation in policy is not noticeable in developing countries and the channels are less properly established (Paudel, 2009). The construction industry should be committed to reduce construction waste by efficiently adopting waste minimization strategies in order to reach the goal of sustainability. Therefore, stakeholder participation, adopting adequate 3R and policy for efficient implementation should be taken into consideration for this issue (Nitavattananon and Borongan, 2008). In the construction site, contractor should practices reduce construction waste as much as possible and reuse the waste materials as much as possible in order to minimize the construction waste generated (Hu, 2011).

For example, the rate of recycling the concrete reached 65% in Japan in 1995, and 96% in 2000 (Yang, 2011). Timber wastes were highlighted that it is easy to reuse and recycle and timber formwork commonly can be used for several times. Furthermore, metal wastes obtain as the high recycling rates due to the high profit in the market. There are many ongoing researches for a study on the re-use of waste glass as aggregate for concrete production materials (Tam, 2010). The grinded glass can replace the sand and pozzolan in the production of concrete products and cement (Winkler, 2010).

- ***Awareness and knowledge:***

Public awareness, social media and company newsletters helps to improve construction waste management practices. Thus, it is necessary to conduct training and education activities to enhance the performance of construction waste management practices (Udawatta et al., 2015). Environmental education and protection suggested begin at construction sites and training course for construction employees should be given before work (Wei and Rotter, 2008). Construction Industry Development Board (CIDB) is playing a role to educate the industry's key players with a series of training courses, workshops and awareness raising events (Papargyropoulou et al., 2011). Waste reduction training among on-site staff is also considered important element to increase awareness in order to help them implement a better procedure to reduce construction waste (Begum et al., 2007b). In addition, monitoring programs to ensure compliance of waste management practices with legislation also is a practical ways to implement solutions for construction waste management (Udawatta et al., 2015). For example, the local industry in Hong Kong has been promoting reduction and recycling of construction wastes, provide in-house training on environmental management, and legal measures on environmental protection (Nitavattananon and Borongan, 2008).

- ***Communication and motivation:***

The proactive participation of community in implementing waste management is very important to control waste generation (Petts, 1995). Some attempt to encourage the contractors practice recycling and to motivate their attitudes and behavior towards sustainable construction waste management (Begum et al., 2007b). Attitudes of contractor and industry behaviors should be change towards construction waste reduction. Effective communication amongst all parties those involved was one of the ways to enhance their commitment towards construction waste minimization. It is necessary to communicate the environmental benefits of construction waste management which helps to reduce waste by giving positive feedback rather than punishment (Udawatta et al., 2015). Thus, the development of better communication medium within the provided proper waste management practices training, establishment of waste allowances and incentives would help to improve its performance waste management in the construction industry (Kulatunga et al., 2006).

- ***Available technology:***

Prefabrication components are a sustainable practice and popular environmentally friendly construction approach to reduce the amount of construction wastes generated on site such as Industrialized Building System (IBS) (Ho, 2001; Papargyropoulou et al., 2011). The average rate 52% of construction waste be reduced by the using the prefabrication component (Jaillonet al., 2009). Thus, Industrial Building System (IBS) introduced as one

of the solutions to reduce construction waste generation on construction sites (Hassan et al., 2012). The achievement of construction waste reduction significantly improves after adopt the prefabrication methods (Wang et al., 2015). Prefabrication component also can significantly reduce the concrete waste produced on construction sites (Poon, 2007). Prefabrication component is more conducive to reduce construction waste compare with the traditional cast in-situ construction method (Lu and Yuan, 2013; Hassan et al., 2012; Wang et al., 2015). However, contractor revealed moderate agreed because IBS technology can only be used for big or costly development projects; since it requires experts to handle it (Ng et al., 2015b). Besides that, waste minimization can carry out through the accurate measurements to minimize construction waste effectively at an early stage by using computerized or Computer-Aided Design (CAD) (Wang et al., 2015) and Building Information Modeling (BIM) materials (Udawatta et al., 2015).

Conclusion:

Construction industry is the major contribute to the solid waste in the world. Even the level of awareness on environmental and sustainable construction waste management is low, the government should rise up the awareness and important of 3R among construction contractors. The sustainability is a popular word today and it is not a new topic. Reduction of construction waste as a appropriate approach towards sustainable construction waste management. Contractor should manage construction waste through 3R as it is sustainable.

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