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Strategic Framework for Construction-Waste Management: Facilitating Sustainable Development in Jordan

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Abstract: Sustainable development is the need of the hour that needs to be incorporated by every industry in every country around the globe. The construction industry is one of the most contributing industry to the major economies around the world. Moreover, the waste it generates needs to be strategically taken care of. In most countries including Jordan, the management of waste generated by the construction industry does not have a proper disposal system. National sustainable development requires a strategic framework that needs to be designed to engage all stakeholders in the construction-waste management process. The impacts of this process must also be thoroughly understood in regard to various environmental issues. Indeed, the construction industry is a major waste generator; such a framework thus provides guidance during the construction life cycle to reinforce waste-management quality. Here, the most fundamental principle is that of the "Three R's" (i.e., reduce, reuse and recycle). The construction-waste disposal process must employ these elements as pillars to reinforce other principles of sustainable construction, thus, forming appropriate strategic guidelines. This study investigates construction waste issues in Jordan through the identification of four main components (i.e., guidelines, technology, policy and regulation), in line with project life cycle and Three R's principle, for ensuring the sustainable handling of construction waste. This study discusses a related conceptual framework designed to facilitate a sustainable construction-waste management process. The study will help in improving the existing condition of Jordan due to the haphazard caused by the construction industry. It will also be useful to other countries that are facing the same issues and are in a similar economic framework.

INTRODUCTION

The Jordanian Construction Industry is a key player in achieving positive economic and social growth. The industrial sector of Jordan has been flourished and contributes approximately 30% of the total national GDP. Thereby, it helps in stabilizing economic development, creating employment opportunities, providing investment opportunities for locals and Foreigners working in Jordan. The construction industry also makes use of a large amount of energy and resources. On the other hand, it has negatively impacted the urban environment by leaving many tons of untreated Construction waste and Demolition (C&D) products throughout cities and neighborhoods. This results in a reduction in the amount of open-space land available, thereby, it does not leave space for a green environment. The land that can be used for other purposes is being occupied by waste instead. The society, environment and economy are the three areas that have been affected due to the improper disposal of the construction waste. Sustainable development in the construction industry adheres to the fact that buildings that are economically, socially and environmentally sustainable. Here, sustainable does not mean making use of naturally available resources but it focuses on making the most optimum use of the resources that been utilized. The construction industry makes use of many resources and the unused resources are rather dumped in lands that can be used for rather a useful purpose. Of the 2,077,215 total cubic tons of Municipal Solid Waste (MSW), 2.7 million consists of construction waste m^3/year (Sweep Net-GIZ, 2013) and is estimated to reach 5.2 million cubic tons by 2034. Government authorities are thus, seeking appropriate ways to manage this issue. However, they have not been able to resolve the issue of the MSW management spectrum entirely. Moreover, they have begun to focus on issues related to C&D waste management, treatment, recycling and the waste-to-energy process. For instance, the Jordanian government approved its first national solid waste management strategy in September 2015 with Decision No. 11392/02. As a national strategic objective, the focus has been shifted from the previously inefficient, costly and environmentally detrimental municipal solid waste management system towards the adoption of a more modern integrated program. Although, this strategy is based on the Three R's (reduce, reuse and recycle), yet it was insufficient in resolving the issue of construction waste. There are insufficient data concerning its true size and volume. Research is thus needed in order to develop and design methods and tools to reduce as well as prevent the accumulation of these materials. While Jordanian officials have taken major steps to deal with waste in a more general sense, a comprehensive strategy is still needed to focus on the construction-waste problem. In tackling this issue, one must first formally identify what constitutes construction waste, thus, providing a way to focus on the necessary tools and in turn, means to achieve reduction. Focusing on the aspect of firms that are engaged in the construction industry, disposal of waste in an efficient manner incurs them in unreasonable costs.

Construction waste: Thousands of tons of construction waste are accumulated annually, thus, posing substantial negative impacts on the environment and economy. Construction waste disposal is a complex issue because garbage is generated during all project activities, including site planning, transportation, storage, materials handling, onsite operations, segregation, reuse, recycling, and final disposal. There are two types of construction waste: physical (e.g., materials, labor and machinery) and non-physical (e.g., time and cost) (Nagapan *et al*., 2012). However, waste management poses serious impacts to end cost, quality, time and the environment. Sustainable construction is defined as "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles". In simple terms, sustainable construction not only helps in maintaining and preserving the environment but along with it also helps the builders in construction in reducing the cost. On the other hand, the United States Environmental Protection Agency (EPA) (Anonymous, 2018) defines it as "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction". It focuses on creating structures that are not only environmentally sound but also that does not disrupt the flourishing environment in any way. Thereby, sustainable development is of the view that involvement in construction activities and earning reasonable profit without destruction of the environment before, during and after the process. Further, six principles for sustainable construction were outlined by the International Council for Building (CIB) Agenda 21 (Kibert, 2012). Sustainable construction throughout the construction life cycle requires maximizing resource usage, minimizing resource consumption, the use of renewable and recyclable resources, protecting the natural environment, creating a healthy and non-toxic environment and achieving quality in the built environment (Hossain *et al*., 2016). The main principles of maintaining sustainability in the construction industry can be defined as the rational use of construction materials, reusing and recycling when possible, properly designing a building in consideration of its life cycle, methodologically analyzing all construction processes, looking out for human needs and benefitting the environment through the same. The most challenging part of sustainable construction is finding solutions that secure qualitative, quantitative, materialistic and psychological benefits for the building's end users. On the other hand, many current construction practices entail the unsustainable use of depleted natural resources and generate significant waste. These waste are not efficiently managed and thereby, causes pollution in the

environment. These issues are also associated with both the building design and construction industry itself. Indeed, international agencies have indicated that there are significant impacts on air quality due to massive amounts of related energy consumption; this consumption is estimated to increase 53% by the year 2030 (Oh *et al*., 2010). An increase in energy and resource consumption does not account for renewable resources that can be generated again. Urbanization is the main reason that the construction business has gained a boost. Due to an increase in population, the need for food, clothing, shelter, and land is rising. Water consumption, urban land use and the continued growth of human settlements will further impact this problem. The other implied problem of improper disposal of construction waste is blockage of water resources. Water resources are wasted as well as waste is dumped in the rivers and canals. This depicts the environmental degradation that the construction industry does. It is estimated that 70 million tons of waste are produced by construction industries (Musakwa *et al*., 2013). Although, most studies identify the amount of waste generated through the construction industry, there are negligible studies that discuss the waste managed through various programs.

There are several problems related to construction-waste management, including the current paucity of sustainability strategies, lack of stakeholder knowledge, regulation violations, insufficient government policies and outdated technology. These factors hinder overall sustainability. Thereby, in turn, it is crucial for the government to develop appropriate initiatives, policies and techniques that emphasize the importance of waste management in attaining a sustainable construction industry. It is also important to outline the importance of sustainable design principles and strategies over project life cycles, as these provide integrated sustainable construction-waste management guidelines for designers, engineers and management firms. The main principles of sustainable construction design (i.e., resource economization, building design life cycle and the human effect). Here, a sustainable building life cycle must be established throughout the pre-construction, construction and post-construction processes. The pre-construction process should involve a substantial consideration of waste reduction (e.g., choosing appropriate and/or non-traditional construction materials, a suitable construction system, implementing sufficient technology and conserving energy) while the construction phase should implement adequate scheduling to reduce the on-site footprint (i.e., separating on-site materials, employee training, water conservation and gray water usage) and the post-construction process should appropriately handle all waste (i.e., demolish all unneeded buildings, dispose of unwanted materials, minimize the human footprint and ensure environmental protection). This gives sufficient reasons as to why the construction waste should be disposed-off properly (Aksel and Eren, 2015).

In accordance with the firms engaged in the construction industry, the disposal of the waste generated by the results at a reasonable cost. This is the main reason that firms refrain from proper disposal of construction waste and instead, throw off the waste in any condition polluting the environment. Pollution of the environment is not the only reason that sustainable strategies should be adopted for managing construction waste. Sustainable construction helps in reducing the waste and thereby, in turn, reducing the cost that incurs for disposal of the same. This study aims at identifying and providing sufficient reasons for adopting and developing a strategic framework for construction waste management. Therefore, the study will be instrumental in addressing the problems caused by improper waste disposal by the construction industry by giving it a new strategic framework developed by the study.

Sustainable design principles and strategies
Sustainable construction development:

- Resources economization of raw materials
- Building design life cycle
- Human effect

Sustainable strategies:

- Energy consumption
- Pre-construction
- Resources preservation
- Water-land usage
- During construction
- Site planning
- Raw materials usage
- Post-construction
- Human welfare

Literature review

The United Kingdom: A combination of regulations, economic instruments and voluntary agreements constitute the general UK strategy to reduce waste. In 2016, the nation produced 222.9 million tons of waste, with 41.1 million of that attributed to construction (DEFRA., 2019). However, there have been significant C&D waste reductions at 104 million tons of garbage and 13 million tons of unused materials per year (DEFRA., 2019). In addition to achieving established targets for ethical, social and environmental performance in driving its waste-management agenda, the UK government has also focused on ways to reduce the amount of construction waste that enters landfills; this is a key legislative strategy for achieving sustainable construction practices, efficient waste management and other fiscal measurements that will drive the construction industry toward a closed-loop manufacturing system. The project life cycle in such a system may also benefit the economy and ecology in the context of green and sustainable development practices. The implementation of related policies, regulations and guidelines constitute a robust approach to achieving sustainable development

throughout the World Business Council for Sustainable Development (WBCSD 2010 cited by Tost *et al*., 2018). The UK has also adopted a sustainable guideline known as the waste hierarchy which is based on the Three-R approach. This principle is used as an overarching guideline to facilitate waste avoidance and a reduction in a variety of design projects. Here, the reduction is the most effective environmental approach to C&D waste generation resource conservation, increasing building life cycles, ensuring renewable energy usage and educating and spreading awareness among the public and private sectors. On the other hand, reuse entails that a given material is used in another application without changing its form (Kibert *et al*., 2016). Finally, recycling involves altering materials into new forms when direct reuse is not possible. Because of its negative environmental impacts, the disposal should be considered only when no other options are present. Udawatta *et al*. (2015) in their study concerning improving waste management in construction cited Coventry *et al*. (2001). They addressed the two fundamental reasons for reducing, reusing and recycling waste (i.e., the economic advantages and environmental advantages). The environmental advantages involve minimizing the immediate risks while avoiding both environmental pollution and harm to human well being while the economic advantages entail lower project costs and increased business patronage. However, the Three-R approach is not practically related to all parameters of the design environment; for instance, waste generation is unpredictable during the architectural design stage. In the year 2012, the UK thus introduced the Waste and Resources Action Programme (WRAP) which helps in facilitating on-site auditing, construction-waste management and cost analyses to deal with waste that has already been produced. On the basis of client awareness of the importance of waste prevention, eight key areas are outlined: designer knowledge, following guidelines and standards during the design process, contractor commitment to the building schedule, water conservation during all stages (from site excavation to key handling), waste and cost reduction among specialists and workers, rehabilitating existing structures (with the goal of making them environmentally friendly), efficient use of materials and waste resources and the products of material usage (e.g., waste at construction sites). Starting with water conservation, this strategic framework considers all construction activities, from the beginning of the project until its completion and usage (i.e., the project life cycle). This is seen as a holistic approach to waste management that deals with all parties involved in the generation of construction waste (Fig. 1).

Malaysia: Malaysia has established a construction development board (CIBD) (Ganesan, 2019) which emphasizes the roles of key stakeholders in achieving a sustainable construction industry. The government also

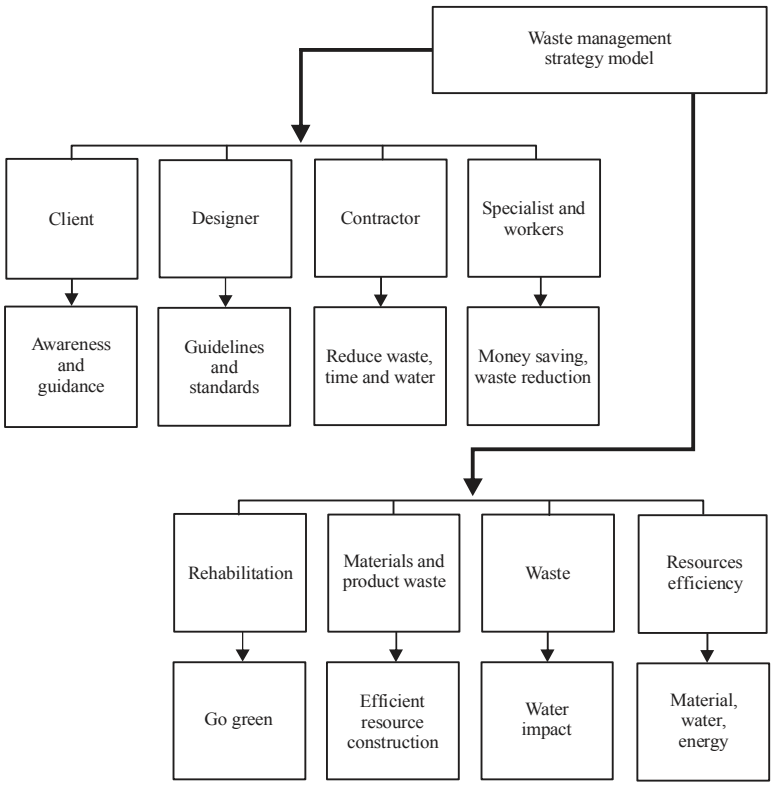

Fig. 1: Construction-waste management framework

developed a standard guide Specification for Building Works (SBW) which objectively targets construction pollution. Further, the country is now adopting Industrial Building System (IBS) designed to control construction waste (Yunus and Yang, 2016). Despite its various policies, the Malaysian government still faces a variety of challenges. Its major challenges are on-site waste management, insufficient legislative enforcement, construction-waste classifications, public awareness, a lack of stakeholder agreement and insufficient recycling facilities. This provides an insight into the problems faced due to the construction industry in Malaysia and the resulting strategies that are adopted by Malaysia to address the same.

Singapore: Singapore's Building Construction Authority (SBCA) established a certification scheme for the surveillance and auditing of construction firms to help prevent waste issues (ISO 14000) (Hwang *et al*., 2017) and increase environmental protections. Due to its limited land size, Singapore is also attempting to minimize the amounts of generated waste and recycle as much as possible by aiming for zero landfills through the Singapore Green Plan (SGP) (Chew, 2016). Industries are thus trying to develop new products from recycled materials and have adopted waste-management strategies under the national recycling plan, which is based on the Three-R approach. Many on-site Non-Governmental Organizations (NGOs) are also helping to reduce the amounts of landfill and non-incinerator waste. However, Singapore's unique strategic framework is based on its geography, population density, transportation methods, infrastructure and existing regulations.

China: China is moving toward sustainable development in general and construction-waste management in particular; related actions to reduce construction waste are typically practical solutions (e.g., recycling construction materials from government and road-engineering projects). Principally recycled construction waste from concrete also comprises a flourishing industrial interest. Further, contractors are required to obtain trip tickets that ensure proper construction-waste disposal in designated landfills. The Chinese government has also adopted a Danish waste- management model based on the Three R's (Huang *et al*., 2018). This is because its earlier model was are verse version of the Three R modeling which 80% of all waste was deposited in landfills. Waste reduction was not previously considered a priority. Figure 2 shows the waste hierarchy which is another important strategy that was proposed by Chinese researchers. With the project life cycle as the central pillar, all stages (e.g., design, construction, maintenance and demolition) are focused on sustainability. Such management allows responsible stakeholders to predict waste production and use appropriately recycled materials in their construction projects.

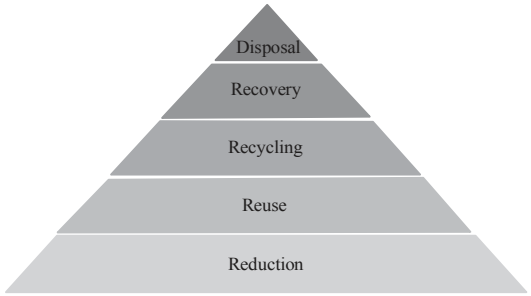

Fig. 2: Waste hierarchy

Table 1: Construction waste by structure type

Structure type	Median of construction waste (Kg m^2)
Residential building during construction	22.0
Nonresidential building during construction	20.0
Residential demolition waste	630.0
Nonresidential demolition waste	780.0

Table 2: Percentage of construction-waste components

Material	Percentage of construction waste
Concrete	30:40
Wood	1
Glass	3:5
Insulation materials	5:10
Asphalt	4
Metal and steel	14
Bricks	15

MATERIALS AND METHODS

This study's research methodology involves a sequential process beginning with a literature review seeking published articles, local government reports, policies aimed at waste management, the results of informal meetings among different stakeholders, government reports, NGO statements and information from professional contractors, engineers and architects. This was done to gain an overview of the strategies and policies adopted by different countries, including regulations emphasizing sustainable construction-waste management. A comparative analysis was then conducted to identify the roles of different stakeholders in this regard. However, there was very little quantitative information on the actual construction-waste problem. As such, the author conducted face-to-face interviews with stakeholders, government personnel, municipal officials, contractors, engineering firms, landfill managers and NGOs working to establish a conceptual strategic framework suitable for Jordan and other underdeveloped countries, especially, those in the Middle East. Tables 1 and 2 for more information.

RESULTS AND DISCUSSION

All collected data were analyzed based on two categories of the building life cycle (i.e., structure type during construction and demolition of the structures and the percentage of waste components).

Structure type during construction and demolition: The residential housing sector produced 22 kg m^2 of waste during construction while demolitions produced 630 kg m^2. On the other hand, non-residential structures generated 20 kg m^2 during construction and 780 kg m^2 during demolition. This indicates that both construction types generate similar amounts of waste. It is evident that current construction methods lack modern technologies (i.e., Building Information Modeling (BIM), new building standards, updated design guidelines, resource reduction measures and recycled materials).

Percentage of waste component: Table 2 shows the major contributors to construction waste of which 30-40% is related to concrete. This is because concrete is used in all construction types. Further, materials such as brick, metal, steel and wood generate less waste. However, these materials are reused rather primitively. It is clear that policies and other legislative efforts are highly needed to prevent the accumulation of construction waste.

Solving these issues requires a conceptual strategic framework designed to facilitate construction-waste management while emphasizing the four central components (i.e., reduce, recycle, reuse and disposal), of sustainable development. This will take a holistic approach that tackles all concerning issues (Fig. 3). Such efforts should lead to significant reductions in waste. Here, each component addresses certain issues:

As the central authority, the government needs to implement policies and strategies that help stakeholders formulate plans to attain sustainable construction. This involves planning short-term, medium-term and long-term multi-level national, regional and municipal master plans for the promotion of a Municipal System for Waste Management (MSWM). Further, this requires public education and awareness as well as private-sector focus on the importance of both waste management and sustainable development. Trained municipal staff are needed in this regard.

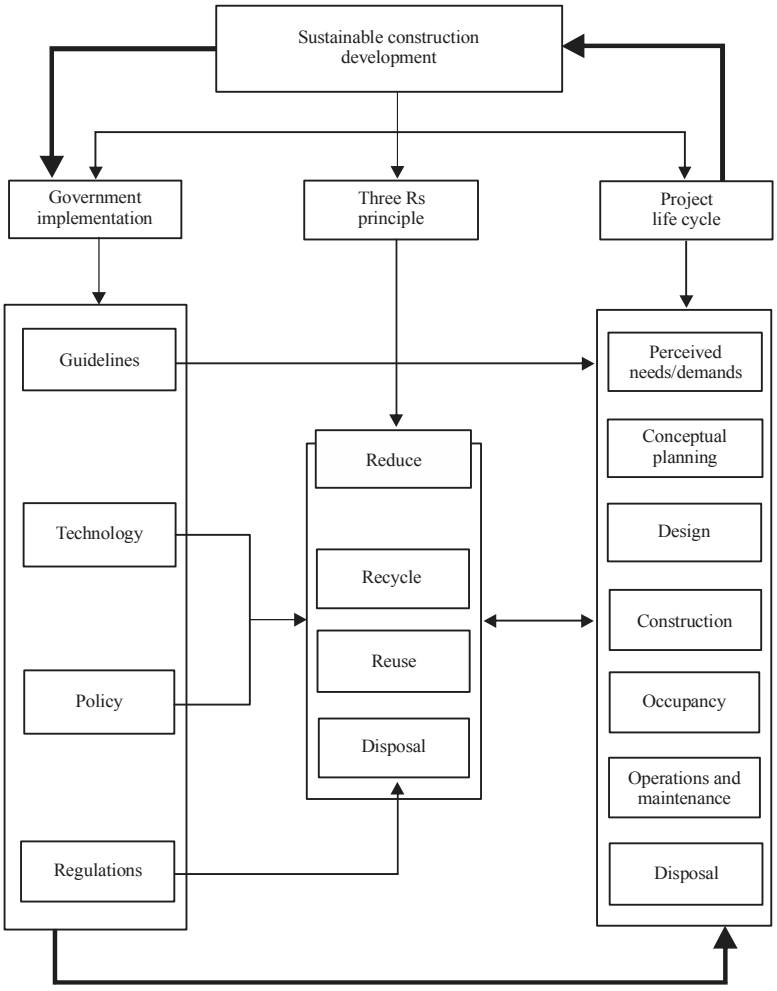

Fig. 3: Strategic framework for construction-waste management

Regulation: This involves tightening actions on violators and precisely regulating all needed measurements. On the other hand, it should reward the builders that follow the rules and regulations. This will help and attract others to do the same. It is also important to consider measurements and tools that promote and encourage the concepts of green building, sustainable construction, investments in recycling and the construction of necessary facilities. This approach will reduce potential waste.

Guidelines: The government should cooperate with academic institutions to establish industrial guidelines as well as technical specifications for designers, architects, engineers and contractors. These should be implemented at the early stages of the project design cycle to minimize waste. Awareness regarding the concerned problems arising out of the construction waste should be spread.

Technology: Sustainable construction leads to sustainable development. However, architects and engineers first need to develop sustainable designs. Construction design firms should thus be encouraged to use new technologies (e.g., BIM 3D and 3-D printing) to save material and labor costs. The government should also reduce taxes on these technologies.

Different strategies have been adopted by different countries based on climate, geographical area, population density, existing environmental regulations, infrastructure, and transportation methods. Here, it is evident that a focus on the Three Rs can serve as a pillar for supporting waste management treatments and disposal issues. As mentioned earlier, Jordan has adopted such a strategy for general waste management. However, there is still a lack of focus on other aspects that affect the construction-waste management process.

The construction life cycle begins with perceived needs and demands before moving to conceptual planning, design, feasibility studies, building, occupancy, operation and maintenance, demolition and disposal. Relevant sustainability issues must, therefore, be addressed in conjunction with the other aspects mentioned above. Sustainable construction should be addressed both earlier and later in the project lifecycle rather than simply during the construction stage.

CONCLUSION

Our future environment depends on systems and initiatives that support sustainable development while allowing urban growth. However, sustainable development is not absolute or easy; humans must make considerable efforts to achieve this status. This requires a dynamic balance between what is ecologically conceivable and the demands of human welfare, equity, prosperity and quality of life. Sustainable development is attained through progress, improvement, evolution, perspective transformations and the quest for wisdom. In a developing country like Jordan, general waste management strategies are still developing. The government can only play a role in providing appropriate guidelines but complying the same relies upon the citizens. As such, there is no comprehensive construction-waste strategy that is developed by the government to address significant issues. However, the scope of developing and implementing a new framework that addresses the problems does exist. Adopting the framework proposed by this study will help to define the construction-waste problem through a comprehensive, holistic approach. Moreover, it is still required to achieve sustainable development in all aspects of the development and construction process. Further research that measures the efficiency and limitations of this model can be done.

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