Journal of Engineering Research

Volume 7
Issue 6 *Issue 6*

Article 19

2023

PESTEL and 3R Waste Management Model for Construction Companies Operating in Central Tanta: A Comprehensive Construction and Demolition Waste Management Model

Moaaz Ali Bastaweesy
Tanta University, Moaazbastaweesy@gmail.com

Mahmoud Ahmed Zaki
Mahmoud.A.Zaki@yahoo.com

Marwa Ahmed Kamer Eldawla
Lecture in Faculty of Engineering, Architectural Engineering Section (Tanta University, marwakamer2009@yahoo.com

Journal of Engineering Research (ERJ
ISSN: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

PESTEL and 3R Waste Management Model for Construction Companies Operating in Central Tanta: A Comprehensive Construction and Demolition Waste Management Model

Authors names [4] By/ Moaaz A. Bastaweesy*, Mahmoud A. Zaki and Marwa A. Kamer Eldawla

affiliation: Doctoral student, President of Tanta University, Assistant professor of architecture faculty of Engineering Tanta University
Email moaaz_ali@f-eng.tanta.edu.eg
mahmoud.zaki@f-eng.tanta.edu.eg
marwaa.kamer@f-eng.tanta.edu.eg

***Abstract*: Construction and demolition waste (CDW) has become a significant environmental issue, especially in developing countries. In Egypt, the presence of large quantities of CDW is a cause for concern, as it poses a significant threat to public health and the environment. This paper proposes a comprehensive waste management model for construction companies operating in Central Tanta, which takes into account the PESTEL factors that are relevant to waste management in the region. The proposed model is based on the 3R (Reduce, Reuse, Recycle) waste management approach and incorporates the use of various waste management techniques, such as sorting, on-site storage, transportation, and final disposal. The effectiveness of the proposed model was evaluated using a survey of construction companies in Central Tanta. The results suggest that the proposed model is suitable for managing CDW in the region and can help construction companies to adopt sustainable waste management practices. The paper suggests that the use of the proposed model could significantly reduce CDW generation, thereby minimizing the environmental impact of the construction industry in Central Tanta. Keywords: Construction and demolition waste, waste management model, PESTEL, 3R, sustainable waste management.recycle) principles. The offered context-specific current international practices, the described current firm practices, and the applied changes are prioritized improvements with inferred sustainability advantages are recommended. The conclusions and suggestions are particularly relevant to other Tanta construction firms that wish to guarantee more environmentally friendly C&DW management operations in the future.**

***Keywords*: 3R strategy; C&DW; construction & demolition waste; solid waste management; waste management hierarchy; waste minimization**

I. INTRODUCTION

The "Global Waste Management Outlook" report produced by the United Nations Environmental Program (UNEP) and International Solid Waste Association (ISWA) reveals that solid waste (SW) generated by various sectors such as households, commerce, the construction industry, and other industries amounts to an astonishing seven to ten billion tons annually [1]. Even more alarming is the fact that nearly 85% of this waste is thoughtlessly discarded in landfills, and only a negligible proportion of waste is recycled or reused. The construction industry, in particular, produces a significant proportion of industrial waste, including construction and demolition waste (C&DW), which has captured the attention of governments and construction corporations [2-3]. Research suggests that the global construction industry uses up almost 40% of the world's resources and energy, 16% of freshwater resources, and 25% of harvested timber, thereby contributing to 13-30% of the world's total waste [4-5].

Variation in the proportion of construction and demolition waste (C&DW) in the overall solid waste (SW) stream is dependent on the region or nation in question. In Europe in 2016, C&DW constituted anywhere from 25 to 30% of the SW stream, while the percentage in Hong Kong in 2014 was noted to be 23%, in the United Arab Emirates in 2010 it was alarmingly high at 80%, and in Singapore in 2011 it was 59% [6-9]. The growing demand for housing and transportation, brought on by rapid urbanization, has caused a boost in the amount of C&DW being produced [10]. In most countries, C&DW is managed conventionally by disposing of it in designated landfills, which can be an expensive process as it involves transportation costs and landfill tipping fees

Journal of Engineering Research (ERJ
N: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

that can vary significantly depending on the country [11-12]. Consequently, there is a push for countries to adopt alternative methods of waste management, such as the application of lifecycle assessment to municipal solid waste management. Many European and certain Asian countries have put some sustainability programs in place with a view to reducing waste disposal [13]. Researchers have suggested that system dynamics and grey model theory could be utilized to minimize unlawful waste using C&DW models. They have also proposed blending inorganic construction wastes containing CaO (like waste gypsum) with Portland cement to encourage recycling and reduce disposal [14-15]. Asian countries, particularly those in Central Asia, which are in a period of rapid development, require significant interventions in waste management. To that end, architecture is regarded as a micro-ecosystem that interacts with the broader ecosystem. The implementation of sustainable concepts has become a critical factor in professional practice [16-20].

II. METHODOLGY

This study commenced with a comprehensive literature review and inquiry to identify waste production processes and international best practices that correspond to both the external variables of the Kazakhstani construction industry setting and the internal factors of the company's operational profile. Subsequently, a C&DW model was developed, integrating the PESTEL and 3R approaches, to assess the company's C&DW management performance from a broader perspective, including the drivers and barriers affecting it. While PESTEL analysis was utilized for organizational and external evaluations, 3R technique was employed for operational-level assessments. Figure 1 outlines the methodological approach of this study.

PESTEL analysis, regarded as an extensive environmental screening technique, aims to identify and appraise the significant macro-environmental factors that may influence the working conditions and business performance within a sector. It is considered as a potent technique for constructing reliable future scenarios and efficient business models, and an effective framework for strategic decision-making. The construction industry involves complex and diverse interconnections of numerous macro-environmental factors that impact a company's operations either directly or indirectly. The PESTEL approach can be utilized to identify crucial external macro factors anticipated to potentially affect Kazakhstan's construction market, along with the company's (including C&DW management) long and medium-term performance.

As a result, in the current study, the external and organizational drivers, as well as the barriers of C&DW management for the CC and its performance on management, have been evaluated using PESTEL through focus-group studies and interviews with the participation of the field experts and the representatives of the CC, discussing their effectiveness as well as their fit onto one another. This might show the company where it has to strengthen itself to increase efficiency.

For the internal evaluation, there were four key factors taken into consideration: tasks, people, formal and informal organizations. Self-government is prevalent throughout every division and every construction site within the division thanks to a complicated hierarchical organizational framework. For instance, the CC started a campaign to sort building debris on-site, but the program was only partially effective since only certain construction sites followed the advised sorting procedures, while others showed neglect. Similar to the above, workforce search, training, education, and other relevant procedures may help to enhance people's level of awareness and attitude toward waste management, which is a crucial aspect of waste management [27-28].

15 experienced employees participated in a semi-structured in-depth interview, a qualitative research technique that involves in-depth interviews with a small number of respondents, in order to better understand the level of awareness regarding C&DW management as well as the general attitude of people toward waste management in CC (5 managers and 10 on-site workers). The primary concerns during the interviews were (1) whether the employees were aware of CD&W management strategies and practices, (2) whether they thought on-site recycling was feasible in CC facilities, (3) the most efficient ways to reduce waste, (4) whether they believed they were well-

Journal of Engineering Research (ERJ
N: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

informed on waste management, and finally (5) the primary reasons for improper waste management in CC facilities.

Reduce, Reuse, Recycle, Compost, Incinerate, and Landfill are the major steps of integrated waste management. With Reduce having the lowest environmental impact and Landfill having the most, these phases have been selected and arranged hierarchically. A procedure based on the availability and application of numerous choices sorted, assessed, and then chosen in accordance with the supplied hierarchy is used to identify sustainable solutions to apply to waste management challenges. A stage's environmental impact rises as it descends the hierarchy; for example, reduce has the least environmental impact while landfill has the most [29].

Reduce, Reuse, and Recycle, often known as the 3R method, are the main factors that contribute to trash minimization (30–32). The 3R technique, which is the most widely used in many nations and has been shown to significantly reduce C&DW and especially high recycle rates, has also served as a basic guideline for this case study.

With its various existing and prospective residential, infrastructural, and industrial building projects in Tanta, the case company (CC) investigated for this research is one of the largest and fastest-growing construction firms. The CC could be regarded as a very good overall representative of contemporary construction companies operating in Tanta given that it operates in almost all of the country's geographical regions and that its operations also extend throughout the rest of for various construction projects including residential, infrastructure, and industrial buildings as well as numerous partnered projects [30].

With its various existing and prospective residential, infrastructural, and industrial building projects in Tanta, the case company (CC) investigated for this research is one of the largest and fastest-growing construction firms. The CC could be regarded as a very good overall representative of contemporary construction companies operating in Tanta given that it operates in almost all of the country's geographical regions and that its operations also extend throughout the rest of for various construction projects including residential, infrastructure, and industrial buildings as well as numerous partnered projects.

Inert waste (60%) and non-inert waste (35%) make up the majority of the trash generated by the CC's construction operations, with just 5% typically needing to be disposed of in a landfill, according to waste composition statistics given by the CC (detailed waste composition is shown in Table 1). In this sense, "inert waste" refers exclusively to things or products that do not significantly change in terms of physical, chemical, or biological composition; it does not, however, include dangerous or environmentally friendly elements. Although the business claims that 95% of the CC's C&DW might possibly be recycled or utilized again, the majority of it now ends up in landfills [31].

Table I. Waste composition data for C&DW generation at the CC

Waste Constituent	%
Inert reusable/recyclable (total)	**60.0**
Concrete	**18.6**
Bricks	**18.6**
Autoclaved cellular concrete	**4.2**
Façade materials	**3.6**
Decoration materials	**15.0**
Non-inert reusable/recyclable (total)	**35.0**
Metal	**20.3**
Timber	**10.9**
Paper	**1.8**
Plastic	**1.8**
Glass	**0.4**
Other, non-reusable/recyclable (total)	**5.0**

III. RESULTS and DISCUSSION

Journal of Engineering Research (ERJ
N: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

A. Drivers of C&DW Management in the CC, both internal and external

Preliminary results from the PESTEL (Table 2) examination of external variables indicate that while certain external factors that might potentially affect the performance of the CC in waste management do exist, they have little practical impact because to a lack of robust laws and/or enforcement in this area. For instance, building businesses disregard an environmental law (Art. 301, item 18 in the Environmental Code of Egypt) that prohibits the dumping of specific construction materials in landfills. Additionally, the volume of created garbage does not match the size of the country's entire waste management industry.

Table II. Results of PESTEL analysis for current C&DW practices at the Case Company (CC)

Political Factors	Economic Factors	Socio-Cultural Factors
Existing political stability. Residential construction defined as one of the main directions of the Government's development strategy "Kazakhstan-2030". State program "Development of construction industry and production of construction materials for 2010-2014". State program for the "Modernization of the Solid Waste Management System for 2014-2050".	Cost to dispose in landfill lower than recycling. Low wages resulting in a high turnover rate of on-site workers. Lack of a stable and responsive market for recycling of waste. Negative consumer perception for materials made of recycled aggregates Low landfill tipping fees.	Poor knowledge on waste recycling/reuse. Low level of motivation for waste sorting/recycling/reusing Conservative culture of construction design loyal to out-of-date practices. Low level of collaboration for waste minimization between managers and on-site workers.
Technological Factors	**Environmental Factors**	**Legal Factors**
Lack of strong policies and Lack of specialized and affordable equipment for on-site reuse of materials Lack of recycling plants in the country. No established prefabricated design and construction technologies.	Existing practices of illegal (wild) dumping and on-site filling at some regions in the country. Existing practices of disposal to landfills (normally not allowed by law) at some regions in the country.	Lack of strong policies and regulations against landfill disposal. Lack of incentives for waste management. Environmental code that is not enforced: "Construction materials' wastes are unacceptable for landfills - Art.301, item 18 of the State Environmental code".

Less than half of the interviewees were knowledgeable of C&DW management and associated practices, according to the results of the interviews. After a brief introduction, the majority stated that good resource planning at the beginning, sorting, and recycling are the most crucial and successful procedures for the CC. The majority of the on-site employees concur that more details on waste management should be supplied, indicating that they

Journal of Engineering Research (ERJ
N: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

are aware of their lack of knowledge and feel the need to advance through the proper procedures and training.

Additionally, supervisors and on-site staff concur that a lack of motivation is a significant factor in the improper handling of garbage at the location. According to the interview's findings, it is recommended for all CC employees to become more knowledgeable about the 3R approach, more waste management training should be given, and staff motivation should be addressed for more efficient waste management [32].

In response to the survey results, the CC held training and knowledge-sharing workshops for more than 500 of its workers as well as the staff of their contractors. This was done to raise awareness of waste management and, in particular, to encourage on-site garbage sorting among the participants. It should be highlighted that due to the high staff turnover rate now in place, it will be necessary to repeat this training frequently in the future in order to maintain a workforce that is well-v According to the region's observed cultural perspective, neither Tanta's civil society nor businesses like the CC have historically placed a high priority on trash management. The observed lack of knowledge about waste management in both the public and private sectors has resulted in a society that is by no means a "green society," showing a general lack of awareness about waste management in C&DW management operations.

The CC, in the past, has been more reactive to C&DW problems rather than proactive that is, by responding to emerging problems only after their occurrence. This was caused by an absence of a waste management vision and a consistent methodology and by a lack of experience resulting in missing best practices and competency in waste management. The CC, thus, focused on the elimination of existing waste problems rather than trying to reduce the waste from the beginning as well as planning for reuse and recycling. Financial information provided by the CC for the years 2014 and 2015 shows that the cost of disposing of construction trash increased annually by 70% while the cost of acquired materials increased annually by about 30%. Due to this imbalance, the CC decided to develop a waste management program in 2016 and begin concentrating on effective waste management techniques.

The PESTEL research reveals that Kazakhstan has an "official" goal for creating waste management regulations. The absence of any incentive from a legal or economic standpoint, the low awareness level, and the low level of technology variables favoring garbage recycling, however, demonstrated the contrary. The CC's waste management is now seen as reactive rather than proactive since it still mostly deals with the garbage that has already been generated (such as sorting). This is brought on by:

- A lack of a unified vision and strategy for waste management;
- A lack of standardized internal waste management techniques;
- A lack of knowledge, proficiency, and best practices in waste management.

The relationship between each single component, also known as a "Fit," is depicted in Figure 2 and may be inferred as follows after the study of each individual component of the congruence model.

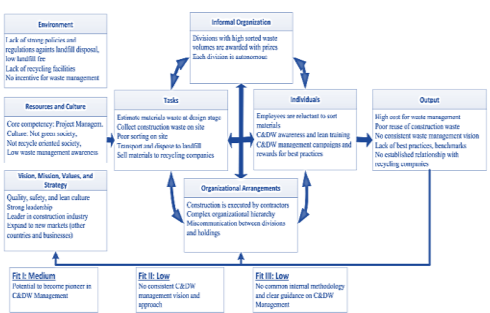

Figure 2.: Drivers and barriers (PESTEL) analysis, individual congruence model components, and the interrelationships between them

- Fit 1: How well the CC's mission, vision, values and goals fit with external factors?

Medium: The current strategy of the CC emphasizes expansion into new markets and growth. Given Kazakhstan's limited capacity for effective waste management, the CC's purpose, vision, values, and

Journal of Engineering Research (ERJ

N: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

goals make sense in light of the surrounding circumstances. However, the CC has a lot of opportunity for development in its waste management program to perform in marketplaces that would present many external elements given its ambition to rank among the top 100 construction firms in the world. Working in such an environment would also provide them with the chance to break new ground in Tanta's C&DW management.

- Fit 2: How well the internal organization fits with the CC's vision, mission and goals?

Low: The CC places a high priority on lean management practices, which by them by nature presuppose an ongoing effort to reduce all forms of "waste" (time, labor, etc.). Despite the fact that the CC had some success implementing lean, leading to better processes and lower labor costs, this did not convert to a drop in SW since the firm lacked a unified strategy that would lead to effective C&DW management.

- Fit 3: How well the components of internal organization fit with each other?

Low: This is due to a number of factors, including a complicated organizational structure, highly autonomous divisions, a traditional approach to design and construction, and the involvement of a small number of employees, which leads to the absence of a standardized internal methodology and clear waste management guidelines.

B. Results of R-Based C&DW Management Practices

Figure 3 presents a review of the various 3R techniques in the building value chain and the associated CC applications. In addition, Table 3 provides a summary of the main advantages and difficulties we have encountered when implementing 3R techniques. The next three subsections provide a thorough description of the chosen recommended approaches as well as observations from tested 3R implementations.

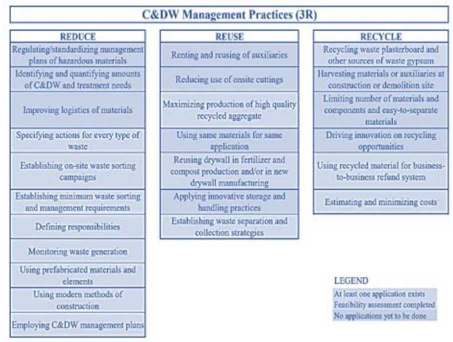

Figure 3. The case study business uses practical 3R tactics for the Central Asian environment in the building value chain and related applications.

Table III. The 3R strategy's biggest advantages and difficulties encountered at the CC

Most Significant Benefits		Challenges
Reduce	Can be implemented independent of third parties. May lead to significant cost savings. Automatically decreases future waste management efforts.	Needs to be implemented mainly at the design stage.
Reuse	Reduces some of the need for new materials purchase	Lower potential cost savings compared to Reduce and Recycle. May require additional resources or third-party involvement (equipment and/or expertise). Properties of individual

Journal of Engineering Research (ERJ
N: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

		materials are important for possible implementation.
Recycle	Highest potential cost savings among 3R elements. May create revenue by selling material. May help create a waste-free construction site, thus lead to space savings. May help build a positive reputation for the company	May require additional resources or third-party involvement (equipment and/or expertise). Requires good sorting practices.

C. Reduce Strategy-Based Practices

One may argue that the primary phase in C&DW management is reduce. The easiest method to decrease waste is to avoid producing it, hence this step should ideally begin early in the project's design phase [33]. According to the available research, inappropriate design, such as too many cut-offs, is the primary cause of waste production [34-36]. The design phase often calls for a thorough, thoughtful, and imaginative approach. Although there are other approaches to reducing C&DW, building information modelling (BIM) technology and the use of prefabricated materials are the most popular and efficient ones.

Digital models of buildings that include all relevant technical (geometry, quantity, and material properties) and functional (schedule, costs, and resource) information are called BIM technologies. BIM is used to enhance planning and scheduling [37] and to prevent design flaws and reworks [38-39] while also assisting in the early detection of incompatibilities in projects. Through BIM-based design validation, the benefit from the adoption of BIM can result in a large decrease in mechanical change orders [39].

BIM facilitates communication among project stakeholders, improves quality, and ensures just-in-time delivery. The CC estimates that about 90% of the pre-prevented trash after the initial deployment was made of concrete.

The process of building with prefabricated materials, sometimes referred to as Industrialized Building Systems (IBS), involves manufacturing and assembling materials or components away from the construction site at a specialized facility. The parts are then combined to create a finished component. The use of prefabricated materials enables lowering waste creation on-site as well as drastically reducing building time when compared to the typical method of employing raw resources for on-site component manufacturing.

Precast facades, stairs, partition walls, bathrooms, balconies, and slabs are common examples of prefabricated materials. Prefabricated materials have been researched for their quantitative benefits, and it has been projected that their usage may replace 70% of on-site finishing tasks and minimize waste associated with concrete and lumber by between 51 and 60% and 74 to 77%, respectively [40-41]. The traditional building, where all materials were cast on-site, creates 1.5 times more waste than mixed construction and three times more waste than IBS, according to a comparative study comparing conventional, mixed, and IBS constructions by Lachimpadi, et al. (2012) [42].

Prefabricated materials are used sparingly in the CC, and all concrete and monolithic works are cast on-site using timber formwork. The low degree of use of prefabricated materials can be attributed to the fact that on-site casting of concrete is more cost-effective, although taking longer to create and producing more waste. The lack of nearby facilities that manufacture prefabricated materials is at least partially to blame for this. As a result, ordering such goods from overseas raises expenses, but importing them from Russia, the

Journal of Engineering Research (ERJ
N: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

neighbor with the most active economic connection, would keep those costs from rising much. The usage of prefabricated materials in construction may result in more incorrect connections and leakage issues, which might eventually affect the stability and strength of the structures, according to technological disagreements. However, this is more of a quality concern because in many situations, these potential issues have been addressed in the past by emphasizing procedures that result in the development of suitable joint connections during prefabricated construction.

Although Tanta does not currently have any prefabricated material production facilities, it is possible to order some types of prefabricated materials from other countries, with Russia being the most popular option. It is also appropriate to suggest employing partially prefabricated materials (mixed construction), such as partition walls or facades, rather than suggesting a complete changeover to just prefabricated materials, given all concrete casting is now done on-site using formworks. An easy transition from conventional to prefabricated building could be possible with the use of partially prefabricated materials. However, the context and other outside elements, such as price, scheduling, procurement, and quality, also have a role in how this choice is used. On building sites with strict deadlines, using partially prefabricated components is currently preferred due to the added time savings advantages that may offset higher prices. Finally, but equally crucially, Kazakhstan is just recently establishing the practice of employing partially prefabricated materials, which has already been applied successfully by various enterprises in specific building sites.

With their original waste management scheme, which was only partially effective, the CC was able to create 60,000 tons of garbage in 2016, which is a decrease from 75,000 tons in 2015. According to the literature [42], using half-prefabricated materials for construction would result in an additional 1.5-fold reduction, bringing the total potential waste reduction from 60,000 tons to 34,000 tons if both measures are fully implemented. This would result from effectively following BIM-based procedures, which would help reduce the amount of waste by about 15%. It should be noted that the CC has already used BIM, and that some of its rivals have lately done the same with the use of partially prefabricated components in their building projects. As a result, the projected reduction potential is realistic.

Understanding the benefits of using BIM technology for C&DW management is particularly crucial. In the current case study, BIM technology implementation is still in its early phases. Since it needs a lot of customization, training, and setup, the procedure is not quick. Once properly implemented, more C&DW reductions will increase the importance of the Reduce stage and automatically decrease the necessity for and relevance of the Reuse and Recycle phases.

D. *Utilizing a Reuse Strategy in Practice*

The Reuse initiative, a component of the 3R approach, attempts to increase a material's lifespan through repeated use for the same purpose as well as by taking advantage of chances for use in secondary uses. It is possible to reuse materials in C&DW management on-site during construction or after it is finished. This is often labor-intensive and depending on the volume and characteristics of the C&DW material [43]. Concrete and drywall have been taken into consideration for the Reuse stage in the context of the current study.

When building roads or foundations, crushed concrete can be used as the sub-base and base, the aggregate for concrete or asphalt, the drainage material, and the cover material [43]. The highest ratio that can be employed depends on the ultimate goal and should be kept to a minimum in order to preserve the qualities of the material to be produced, for instance: Recycled concrete is used in the following ways: 1% for the foundation, retaining walls that support it, the reinforced concrete beam at ground level, and the pile cap; 15% for the drainage layer and hump support; 50% for the rock-fill and filter layer; 15% for the sub-base; and 20% for the block paving [44].

Concrete on-site crushing and reuse in the construction of temporary roads have both been discussed in the CC before. Two pieces of concrete crushing machinery (CCE) have been installed in order to do this. However, there was ultimately no economic gain from the usage of CCEs. The project management claimed that the cost reductions from using CCEs were insufficient to pay for operating

Journal of Engineering Research (ERJ
N: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

expenses. This suggests that while employing CCEs to handle building waste is an excellent choice for environmental sustainability, doing so would not now result in any significant economic benefits. Based on experience, it may be anticipated that 80% of the leftover concrete produced can be recycled or repurposed by CCE for projects other than building roads. For instance, replacement ratios of aggregate with recycled concrete up to 30% allow for the creation of concrete with acceptable quality [44].

Gypsum drywall may be utilized in a variety of other applications, and because it is frequently recovered uncontaminated, the drywall waste produced in the building sector can be simply repurposed and recycled. After processing, it may be recycled into new drywall or used as a soil and fertilizer supplement. Additionally, it works well as a compost component in regions with poor calcium and sulphate nutrient levels.

Gypsum boosts the amount of calcium in compost and can also help balance any acidity that may be present. The possible drawbacks of adding gypsum to compost include a greater requirement for careful monitoring of the temperature, moisture content, and oxygen levels in the compost mixture to prevent anaerobic decomposition-friendly circumstances. Additionally, the acquired product needs to be managed and watched over to have less fragments that resemble paper and are not wanted by the end user. The Clean Washington Centre claims that these particles are undetectable in compost combinations that contain less than 30% gypsum drywall, therefore this is often not a serious constraint [45].

Lastly, the leftover drywall Waste can be sent to other businesses (business-to-business) that are interested in constructing inexpensive structures for other reasons or in reusing drywall in agricultural activities for a variety of applications. This is a workable option for the nation given its status as a developing economy, and it will result in savings for the CC owing to the avoidance of transportation and disposal expenses as well as for third parties due to a decrease in material purchase prices.

E. Practices Based on Recycle Strategy

Recycling is a crucial component of C&DW management, despite the fact that it is the least preferred choice overall in the 3R hierarchy. It is also one of the environmental promises that the public can see the most clearly. Last but not least, it is less expensive to produce recycled materials than resources from original sources during their whole existence. Recycle is not a new concept to certain countries, but it is for the majority of people in Central Asia because it was just recently made known to the public, mostly by the government with the aid of the media. The public has been accustomed to the habit of garbage being either immediately disposed of into vast landfills or burnt in specific instances since the times of the Soviet Union. Some recycling plants have been constructed in Tanta in an effort to limit garbage dumping in landfills. Due to poor awareness of recycling and its associated concepts, as well as a general lack of knowledge about how recycling works and the significance of trash sorting, its operational success is, nevertheless, in doubt. The majority of currently operational facilities accept mixed solid waste (SW) and separate organics from recyclables on the spot, which lowers the amount and quality of recovered materials.

Asphalt, wood, and metal are the three most often used building materials that were examined in this study from the standpoint of recycling. Asphalt is a completely recyclable substance with excellent reuse and recycling qualities. Where used, the utilization of recycled asphalt in the road business is a financially sound alternative that generates considerable savings. Asphalt materials may be recycled using a variety of processes, such as cold recycling and heat generating. The asphalt may be recycled up to 100% more cheaply with the cold recycling process. The outdated asphalt must first be pulverized, though. The Minnesota process, parallel drum process, extended drum process, microwave asphalt, and surface regeneration are among the heat producing technologies. All of these solutions are employed prior to heating and may treat fresh asphalt using a mobile plant [46], therefore they can also be suggested for better C&DW management. Timber is typically seen on construction sites mixed up with other building supplies. Separation is therefore difficult and time-consuming work. Reuse, direct recycling, indirect recycling, and energy recovery are the four main ways that wood waste may be recovered [47]. The greatest choice in this situation seems to be energy recovery.

Journal of Engineering Research (ERJ
N: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

Aluminum, copper, lead, and zinc are the primary metals that may be recovered from C&DW [46]. These metals can be sold to outside companies that will carry out further operations for recycling and reusing them. Zinc may be utilized for roofing cladding, extended flashing, and the fabrication of brass, whereas the recycling rates for lead and copper are 100% and 85%, respectively, in the UK [48]. In order to save a lot of money, the CC started selling metal, plastic, and other commodities in 2016. It is advised that the CC sort the metal more effectively on the site in the upcoming years. According to assessments done with the CC, when sorting is done manually the recovery rate ranges from 5% to 50% and averaging about 20%, with the remaining materials being disposed of in landfills. This suggests that the CC has a lot of space for development. It would greatly encourage waste recycling and assist in achieving higher recycling percentages to use business-to-business refund systems (similar to deposit-refund systems frequently integrated in business-to-consumer systems encouraging end consumers to return especially plastic, metals, and glass for a refund). Magnetic separation techniques should be used to boost the pace at which metals are sorted on-site. In this approach, we anticipate that the average sorting rate may be increased from the present 20% to up to 80% based on the observed composition of the garbage.

CONCLUSIONS and IMPLICATIONS

While analyzing the lessons learnt from current construction waste management methods at one of the top construction firms operating in Egypt (the case company (CC) with the main office located in Tanta), the current paper gives a thorough C&DW management assessment technique. It examines several C&DW approaches based on the literature as well as their successful and unsuccessful results upon adaptation. This is accomplished by taking into account both internal and external organizational dynamics (PESTEL) and examining various operational-level techniques and practices from the standpoint of the waste management pyramid (3R) in the context of the Tanta building industry. For the purposes of this study, supporting evidence for effective waste management techniques from studies carried out in various nations has first been reviewed. Following this, a number of practices for successful waste management have been identified, presented in figures and tables, some of which have since been tried and adopted by the CC. Despite certain regional and continental differences in good practices, they all have a hierarchical organizational structure and may be systematized into the 3R strategy's phases of reduce, reuse, and recycle. The CC was producing a lot of C&DW due to its high volume of building activities. Additionally, the price of waste management operations was rising faster than the cost of purchasing building supplies. Various success has been attained as a result of the problem's recognition and the beginning of the adoption of some waste management strategies. However, the lack of "green practices" at the sectoral level of the country and the low level of incentives and possibilities for sustainable waste management practices meant that the CC also encountered external obstacles that hindered its sustainability efforts. Internal issues resulted from a lack of a standard method or model for waste management, a lack of knowledge and best practices, and some resistance from the workforce and the organizational structure. It is reasonable to suppose that the achievements and present difficulties may be effectively extended to other construction firms operating in Egypt's expanding economy, and that the excellent practices found here as well as the suggestions offered are relevant throughout the area. Long-term gains from strategically putting 3R strategy-based solutions to the C&DW management problems of the Egyptian construction industry will have considerable material and intangible advantages. The following is a summary of the most important conclusions from the current case study, which is based on the Tanta CC but is also extremely applicable to other construction firms working throughout the remainder of Egypt:

- Although Tanta has an "official" vision for creating a waste management guideline, PESTEL analysis has revealed that there is still a sizable gap between the industry's current and ideal levels of C&DW management practices because of insufficient technological factors prepossessing waste recycling, a low degree of development of a "green culture," a lack of awareness, and an absolute lack of commitment.

Journal of Engineering Research (ERJ
N: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

- The initiatives that encourage waste reduction appear to have the most potential to reduce C&DW (compared to reuse and recycling). Since poor or flawed design is one of the primary causes of C&DW, the BIM technology holds great promise for removing related issues at an early stage of the design process.
- BIM has the potential to be an effective reduction technique since it already makes certain subsequent reuse and recycling operations unnecessary by promoting reduction at the outset. Although prefabricate building is also promoted to reduce waste, its application now appears to be less important than BIM.
- The creation of C&DW was still high due to the problems covered in depth in the book, despite some early initiatives that effectively and considerably decreased the overall C&DW. Therefore, more reuse and recycling efforts are also suggested.
- The primary material for reuse was concrete since it can be used as aggregate to make fresh concrete. Given that the CC currently has the crusher equipment, it is advised to keep using it and expanding its applications (e.g., new concrete, for temporary roads, as backfill, as sub-base). Concrete has more promise, although drywall has some as well.
- There is substantial potential for reuse and/or recycling with regard to other materials including asphalt, wood, and metal. Particularly, the potential for off-site recycling of metals (i.e., material to be sold to third parties for recycling) has not yet been fully realized.
- Regardless of the employee's position, there appears to be a lack of employee understanding of the 3R hierarchy and waste management. Because of the considerable staff turnover in the industry, it is probable that already established training programs will be successful but still need to be repeated.

Journal of Engineering Research (ERJ
N: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

REFERENCES

1- UNEP; ISWA. Global Waste Management Outlook; United Nations Environment Program: Vienna, Austria, 2015.

2- Jin, R.; Yuan, H.; Chen, Q. Science mapping approach to assisting the review of construction and demolition waste management research published between 2009 and 2018. Resour. Conserv. Recycl. 2019, 140, 175–188.

3- Ferronato, N.; Rada, E.C.; Gorritty Portillo, M.A.; Cioca, L.I.; Ragazzi, M.; Torretta, V. Introduction of the circular economy within developing regions: A comparative analysis of advantages and opportunities for waste valorization. J. Environ. Manag. 2019, 230, 366–378.

4- Horvath, A. Construction Materials and The Environment. Annu. Rev. Environ. Resour. 2004, 29, 181–204.

5- Thongkamsuk, P.; Sudasna, K.; Tondee, T. Waste generated in high-rise buildings construction: A current situation in Thailand. Energy Procedia 2017, 138, 411–416.

6- EC Waste. Available online: http://ec.europa.eu/environment/waste/construction_demolition.htm(accessed on 10 January 2019).

7- EPD Statistics Unit. Monitoring of Solid Waste in Hong Kong—Waste Statistics for 2014; Environmental Protection Department: Hong Kong, China, 2015.

8- Rogers, S. Battling construction waste and winning: Lessons from UAE. Proc. Inst. Civ. Eng. Eng. 2011, 164, 41–48 .

9- Giannis, A.; Chen, M.J.; Yin, K.; Tong, H.H.; Veksha, A. Application of system dynamics modelling for evaluation of different recycling scenarios in Singapore. J. Mater. Cycles Waste Manag. 2017, 19, 1177–1185.

10- Manowong, E. Investigating factors influencing construction waste management efforts in developing countries: An experience from Thailand. Waste Manag. Res. 2012, 30, 56–71.

11- . Tam, V.W.Y. Economic comparison of concrete recycling: A case study approach. Resour. Conserv. Recycl. 2008, 52, 821–828.

12- Hoornweg, D.; Bhada-Tata, P. What a Waste: A Global Review of Solid Waste Management. Urban development series. World Bank 2012, 1, 1–116.

13- Khandelwal, H.; Dhar, H.; Thalla, A.K.; Kumar, S. Application of Life Cycle Assessment in Municipal Solid Waste Management: A Worldwide Critical Review. J. Clean. Prod. 2018, 209, 630–654.

14- Jia, S.; Liu, X.; Yan, G. Dynamic analysis of construction and demolition waste management model based on system dynamics and grey model approach. Clean Technol. Environ. Policy 2018, 20, 2089–2107.

15- Kim, J.; Tae, S.; Kim, R. Theoretical Study on the Production of Environment-Friendly Recycled Cement Using Inorganic Construction Wastes as Secondary Materials in South Korea. Sustainability 2018, 10, 4449.

16- Ibrahim, M. Estimating the sustainability returns of recycling construction waste from building projects. Sustain. Cities Soc. 2016, 23, 78–93.

17- UNEP. Central Asia Waste Management Outlook; ZOI Environment Network: Châtelaine, Switzerland, 2017.

18- Makhmutova, E.V. Central Asia in Search for Its Own Way of Integration. Mgimo Rev. Int. Relat. 2018, 78–91.

19- Gálvez-Martos, J.L.; Styles, D.; Schoenberger, H.; Zeschmar-Lahl, B. Construction and demolition waste best management practice in Europe. Resour. Conserv. Recycl. 2018, 136, 166–178.

20- Ministry of Justice of the Republic of Kazakhstan. Environmental Code of the Republic of Kazakhstan; ILS Adilet: Astana, Kazakhstan, 2007

21- Inglezakis, V.J.; Moustakas, K.; Khamitovac, G.; Tokmurzin, D.; Rakhmatulina, R.; Serik, B.; Abikak, Y.; Poulopoulos, S.G. Municipal solid waste management in Kazakhstan: Astana and almaty case studies. Chem. Eng. Trans. 2017, 56, 565–570.

22- Inglezakis, V.J.; Moustakas, K.; Khamitova, G.; Tokmurzin, D.; Sarbassov, Y.; Rakhmatulina, R.; Serik, B.; Abikak, Y.; Poulopoulos, S.G. Current municipal solid waste management in the cities of Astana and Almaty of Kazakhstan and evaluation of alternative management scenarios. Clean Technol. Environ. Policy 2018, 20, 503–516.

23- Gi Llespie PESTEL Analysis of the Macro-Environment; Oxford University Press: Oxford, UK, 2011; pp. 1–5.

24- Carruthers, H. Using PEST analysis to improve business performance. Practice 2009, 31, 37–39.

25- Iacovidou, E.; Busch, J.; Hahladakis, J.N.; Baxter, H.; Ng, K.S.; Herbert, B.M.J. A Parameter Selection Framework for Sustainability Assessment. Sustainability 2017, 9, 1497.

26- Buchanan, S.; Gibb, F. The information audit: Methodology selection. Int. J. Inf. Manag. 2008, 28, 3–11.

27- Udawatta, N.; Zuo, J.; Chiveralls, K.; Zillante, G. Improving waste management in construction projects: An Australian study. Resour. Conserv. Recycl. 2015, 101, 73–83.

28- Wang, J.Y.; Kang, X.P.; Tam, V.W.Y. An investigation of construction wastes: An empirical study in Shenzhen. J. Eng. Des. Technol. 2008, 6, 227–236.

29- Peng, C.L.; Scorpio, D.E.; Kibert, C.J. Strategies for successful construction and demolition waste recycling operations. Constr. Manag. Econ. 1997, 15, 49–58.

30- Huang, B.; Wang, X.; Kua, H.; Geng, Y.; Bleischwitz, R.; Ren, J. Construction and demolition waste management in China through the 3R principle. Resour. Conserv. Recycl. 2018, 129, 36–44.

Journal of Engineering Research (ERJ
N: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

31- Memon, M.A. Integrated solid waste management based on the 3R approach. J. Mater. Cycles Waste Manag. 2010, 12, 30–40.
32- Shan, N.L.; Wee, S.T.; Wai, T.L.; Chen, G.K. Construction Waste Management of Malaysia: Case Study in Penang. Adv. Sci. Lett. 2018, 24, 4698–4703.
33- Osmani, M. Construction Waste. In Waste: A Handbook for Management; Letcher, T.M., Vallero, D.A., Eds.;Elsevier Inc.: Burlington, MA, USA, 2011; pp. 207–218. ISBN 9780123814753.
34- Rounce, G. Quality, waste and cost considerations in architectural building design management. Int. J. Proj. Manag. 1998, 16, 123–127.
35- Keys, A.; Baldwin, A. Designing to encourage waste minimisation in the construction industry. In Proceedings of the CIBSE National Conference, CIBSE2000, Dublin, Ireland, 4–5 September 2000.
36- Ekanayake, L.L.; Ofori, G. Building waste assessment score: Design-based tool. Build. Environ. 2004, 39, 851–861.
37- Eastman, C.M.; Teicholz, P.; Sacks, R.; Liston, K. BIM Handbook: A guide to Building Information Modeling for owners, managers, designers, engineers and contractors, 2nd ed.; Wiley & Sons: Hoboken, NJ, USA, 2011; ISBN 9780470541371.
38- Won, J.; Cheng, J.C.P.; Lee, G. Quantification of construction waste prevented by BIM-based design validation: Case studies in South Korea. Waste Manag. 2016, 49, 170–180.
39- Cheng, J.C.P.; Won, J.; Das, M. Construction and Demolition Waste Management using BIM technology. Waste Manag. N. Y. 2015, 27, 159–160.
40- Jaillon, L.; Poon, C.S.; Chiang, Y.H. Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. Waste Manag. 2009, 29, 309–320.
41- Lawton, T.; Moore, P.; Cox, K.; Clark, J. The gammon skanska construction system. In Proceedings of the International Conference Advances in Building Technology, Hong Kong, China, 4–6 December 2002; Volume 2, pp. 1073–1080, ISBN 978-0-08-044100-9.
42- Lachimpadi, S.K.; Pereira, J.J.; Taha, M.R.; Mokhtar, M. Construction waste minimisation comparing conventional and precast construction (Mixed System and IBS) methods in high-rise buildings: A Malaysia case study. Resour. Conserv. Recycl. 2012, 68, 96–103.
43- Cochran, K.M. Construction and demolition debris recycling: Methods, markets and policy. Diss. Abstr. Int.B Sci. Eng. 2009, 70, 1260.
44- Tam, V.W.Y.; Tam, C.M. Evaluations of existing waste recycling methods: A Hong Kong study. Build. Environ. 2006, 41, 1649–1660.
45- Marvin, E. Gypsum Wallboard Recycling and Reuse Opportunities in the State of Vermont; Vermont Agency of Natural Resources: Montpelier, VT, USA, 2000.
46- Tam, V.W.Y.; Tam, C.M. A review on the viable technology for construction waste recycling. Resour. Conserv. Recycl. 2006, 47, 209–221.
47- Taylor, J.; Mann, R.; Reilly, M.; Warnken, M.; Pincic, D.; Death, D. Recycling and End-of-Life Disposal of Timber Products; Forest and Wood Products Research and Development Corporation: Melbourne, Australia, 2005.
48- Lang, J.C. Zero landfill, zero waste: The greening of industry in Singapore. Green. Ind. New Ind. Econ. Asian-Style Leapfrogging 2014, 4, 189–215.