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Analysis of factors affecting construction and demolition waste reduction in Egypt

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ABSTRACT

Construction projects are associated with construction and demolition waste (CDW) generated at different stages. In Egypt's case, the CDW problem has become a significant challenge, anad the need to find sustainable solutions is overwhelming. Based on recent investigations in the literature, it was found that six main factors are affecting CDW reduction (CDWR) as follows: (1) waste-efficient materials procurement measures; (2) waste-efficient materials procurement models; (3) green materials procurement approach; (4) legislation; (5) culture & behaviour; and (6) awareness. In this study, a representative sample of Egyptian construction firms was screened to (1) investigate the applicability and effectiveness of CDWR factors in the Egyptian construction sector; and (2) examine the relationship between these factors and CDWR. The results revealed that (1) among different factors, 'correct materials purchase' is the most applied item while 'reducing overall material use by using prefabricated elements and highly durable materials' is the most effective item; and (2) there are statistically significant positive relationships between CDWR and different factors except 'legislation'. The results demonstrate the necessity of developing a conceptuweal framework, as a next research initiative, consisting of these different factors for CDWR in Egypt.

KEYWORDS
Construction and demolition waste; waste reduction factors; built environment; sustainability; quantitative analysis; Egypt

Introduction

The construction industry is one of the most significant industries contributing to countries' social and economic development. It provides the community with high living standards by providing society with socio-economic projects and infrastructure facilities such as roads, hospitals, and schools. Unfortunately, construction and demolition waste (CDW) is a growing challenge that the whole globe faces (Hussin et al. 2013). According to the latest report published by the World Bank in 2012, it is expected that the amount of solid waste (SW) generated worldwide will increase from 1.3 billion tonnes to 2.2 billion tonnes by 2025 (Hoornweg and Bhada-Tata 2012). CDW constitutes about half of the annual generated SW worldwide (Yılmaz and Bakış 2015; Redling 2018). A report published by Transparency Market Research in 2017 claims that there will be a tremendous increase in the volume of the CDW generated over the coming years (Redling 2018). Unfortunately, the dumping of CDW is a common global trend that negatively affects society and the environment (Slowey 2018). In the Middle East and North Africa (MENA) region, including Egypt, dumping is the dominant practice of dealing with CDW. This action has led to the SW problem's escalation, resulting in severe negative impacts on society, environment, and economy, which are the triple bottom line (TBL) of sustainability (Abdelhamid 2014; Aden 2017; El-Sherbiny et al. 2011; Nassour et al. 2016; United Nations Environment Programme (UNEP)), 2009; Zafar 2016). Accordingly, proper actions and strict measures need to be taken to alleviate the MENA region's CDW problem.

Waste in construction materials represents a severe problem for the Egyptian construction industry (Garas et al. 2001). In Egypt, up to 40% of total construction materials cost is wasted, and this is equivalent to 16% of total building cost (i.e. labour and materials cost). It is worth mentioning that the waste in total materials cost must not exceed 4% under any circumstances (Shamseldin 2003). CDW is dumped on roads and in facilities that lack effective management. Most of the dumping sites are unsafe and marked by the non-existence of sufficient precautions to prevent the self-ignition of waste, leading to environmental pollution (Abdelhamid 2014; Azmy and El Gohary 2017). The biodegradation of CDW in landfills results in severe health and environmental problems (Azmy and El Gohary 2017; Mahamid 2020). Also, CDW negatively impacts the efficiency, effectiveness, value, and profitability of construction companies. CDW severely harms countries' economies and the TBL of sustainability (Memon et al. 2015; Park and Tucker 2017; Jalaei et al. 2021). Caldas et al. (2014) claimed that construction materials and equipment constitute between 50 and 60% of total project cost and affect 80% of its schedule.

Based on several investigations carried out by Daoud et al. (2018a), Daoud et al. (2018b), Daoud et al. (2020a), and Daoud et al. (2020b) about solving the CDW problem in Egypt, several factors affecting CDW reduction (CDWR) were compiled, which helped build the theoretical framework presented in this study. This framework depends mainly on six main factors, consisting of several items, as follows: (1) waste-efficient materials procurement measures; (2) waste-efficient materials procurement models; (3) green materials procurement approach of green building (GB) practices; (4) legislation; (5) culture & behaviour measures; and (6) awareness measures. All these factors are considered

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independent variables (IDVs), affecting CDWR as a dependent variable (DV). In this study, the main aim is to understand and investigate the causes of a phenomenon (i.e. CDWR). In a cause-effect relationship, the presumed cause is called 'IDV', and the presumed effect is called 'DV' (Flannelly et al. 2014). In other words, an IDV is a variable that is assumed to affect another variable (i.e. DV). A DV is a variable that depends on IDVs. Researchers are usually interested in understanding and predicting the DV and how it is affected by IDVs (Flannelly et al. 2014). Each IDV and the DV, which are named constructs, are represented and measured by indicators or items. These indicators were extracted based on extensive investigations as aforementioned. It is worth mentioning that all indicators measuring the same factor are assumed to have equal weights and independent of each other. For straightforward representation of the theoretical framework, each indicator (i.e. item) is given an initial code used later in the data analysis. The IDVs, DV, relevant items, and corresponding codes are tabulated in Table 1, and the theoretical framework is shown in Figure 1.

The detailed aims of this paper are to (1) determine the perceptions and attitudes towards the CDW problem in Egypt; (2) rank the different IDVs based on their effectiveness and applicability in the Egyptian construction sector; and (3) examine the relationships (i.e. bivariate cowerrelations) between the different IDVs and the DV. This paper starts by discussing the research methodology adopted to achieve the different aforementioned aims. Then, the data analysis and results are presented in detail to demonstrate the outcomes of investigating the paper's aforementioned aims. Finally, conclusions and recommendations for future research are presented.

Research methodology

The research methodology, designed to achieve the abovementioned aims, adopts a 'survey' research strategy. The survey strategy is helpful when the researcher tries to investigate both following aspects: (1) attitudes, opinions, and organisational practices; and (2) relationships between different variables, mainly cause-effect relationships (Saunders et al. 2016). It helps collect data from a sufficient sample size to allow generalisation of the findings. The research methodology consists of several steps, as discussed in the following subsections.

Design of the survey questionnaire

The survey questionnaire was divided into five sections main sections. Section one investigates demographic information of the respondents and their firms. Also, it investigates the CDW problem in Egypt and its current status. Section two evaluates: (1) the current applicability of materials procurement models and measures and green building practices within the Egyptian construction industry; and (2) their effectiveness towards CDWR. Section three evaluates the applicability of Egyptian CDWM legislation and their effectiveness towards CDWR. Section four evaluates the applicability of awareness and culture & behaviour measures in Egypt and their effectiveness towards CDWR. In other words, the first four sections evaluate the factors affecting CDWR in terms of current applicability and effectiveness in reaching the goal of CDWR. Finally, section five evaluates the agreement on the expected improvement of different project dimensions (i.e. cost, time, and quality) via CDWR. In other words, the last section (i.e. section five) evaluates the expected outcomes or goals of CDWR, which would result from the effectiveness of the factors behind it.

All the questions used in the survey questionnaire are close-ended. Three types of five-points Likert scales were developed, based on studies of Vagias (2006) and Brown (2010), to answer the sections mentioned above. First, the 'applicability' Likert scale was used to assess the current degree of applicability of different factors contributing to CDWR in the Egyptian construction industry as defined by the literature and investigated in the theoretical framework. In this scale, '1' means 'not applicable at all', and '5' means 'extremely applicable'. Second, 'effectiveness' Likert scale was used to assess the degree of effectiveness of these different factors towards CDWR, in which '1' means 'not effective at all' and '5' means 'extremely effective'. Finally, 'agreement' Likert scale was used to assess the degree of agreement on the expected outcomes of CDWR towards project dimensions' improvement. In this scale, '1' means 'strongly disagree', and '5' means 'strongly agree'. Before proceeding to next steps, the designed interview questionnaire was submitted for review by 'Built Environment and Architecture Ethics Panel' at London South Bank University (LSBU). The ethics application, with ID ETH1819-0067, was approved until 16th of May 2023.

Pilot testing

An initial pilot study was carried out to assess the survey questionnaire's comprehensiveness, clarity and feasibility (Ruel et al. 2018). The recommended minimum sample size for pilot testing is 10 participants (Saunders et al. 2016). The sample included in this pilot test consisted of 30 participants as shown in Table 2, of which 15 participants are industry professionals, and the other 15 participants are academics with more than ten years' experience of industrial work and teaching & research, respectively. Face and content validation were achieved through piloting with the experts mentioned above. Feedback was received from the selected experts, and the survey questionnaire was modified accordingly. The average time taken to complete the questionnaire was approximately 45–60 min from the respondents' feedback. There was a consensus among the selected experts that the survey questionnaire should be designed in Arabic and English. This is due to the complexity of some used terminologies and concepts and that the English language is not the first language in Egypt. Accordingly, this recommendation was taken into consideration. The survey questions were translated, and the survey questionnaire was redesigned to include Arabic and English questions.

As the survey questionnaire was going to be distributed among a large sample size, as discussed later in this paper, it is difficult to repeat the process to get a second round of responses. Accordingly, the internal consistency and reliability of the survey questionnaire were checked before conducting the actual study. It was essential to ensure that the expected responses will be consistent and the used measurement tools (i.e. Likert scales) are reliable before actual data collection (Daoud et al. 2017). Through the pilot testing of the survey questionnaire, Cronbach's alpha was calculated for the different variables included in the questionnaire using SPSS V26© software to check consistency and reliability. All the values exceeded the threshold value of **0.7**, as stated by George and Mallery (George and Mallery 2003).

Sample size – targeted participants

The Egyptian Federation for Construction and Building Contractors (EFCBC) currently includes 28,000 construction

Table 1. Independent and dependent variables with their relevant items and corresponding codes.

Construct (i.e. variable)		Type	Indicator (i.e. item)	Code	References
Materials procurement models (MPMO)		IDV	Specialty contractor procurement model (SCPM) (i.e. the specialty contractor is responsible for procuring materials for the project owner)	MPMO.1	(Daneshgari and Harbin 2003)
			Owner procurement model (OPM) (i.e. the project owner directly procures the required materials from the vendors)	MPMO.2	
Materials procurement measures (MPMR)	Suppliers' low waste commitment (SLWC)	IDV	Suppliers' flexibility in supplying small quantities or modification to products in conformity	MPMR.SLWC.1	(Ajayi et al. 2017)
			Commitment to take back scheme (packaging, unused, reusable and recyclable materials)	MPMR.SLWC.2	
			Supply of quality and durable products	MPMR.SLWC.3	
			Usage of minimal packaging (without affecting materials safety)	MPMR.SLWC.4	
	Low waste purchase management (LWPM)		Procurement of waste-efficient materials/ technology (pre-assembled/cast/cut)	MPMR.LWPM.1	
			Purchase of secondary materials (recycled and reclaimed)	MPMR.LWPM.2	
			Purchase of quality and suitable materials	MPMR.LWPM.3	
			Avoidance of variation orders	MPMR.LWPM.4	
			Correct materials purchase	MPMR.LWPM.5	
	Effective materials delivery management (EMDM)		Effective protection of materials (during transportation, loading & unloading)	MPMR.EMDM.1	
			Effective onsite access (for ease of delivery)	MPMR.EMDM.2	
			Efficient delivery schedule	MPMR.EMDM.3	
			Usage of Just in Time (JIT) delivery system	MPMR.EMDM.4	
	Waste-efficient bill of quantity (WEBOQ)		Accurate materials take-off	MPMR.WEBOQ.1	
			Prevention of over/under ordering	MPMR.WEBOQ.2	
			Reduced waste allowance	MPMR.WEBOQ.3	
Green building practices representing green materials procurement (GBPR)		IDV	Utilising renewable materials and materials manufactured using renewable energy.	GBPR.1	(Housing and Building National Research Center (HBRC) 2011) (HBRC 2017)
			Using regionally procured materials and products extracted or manufactured within a distance of 500 km of the project site with no less than 50% of the total materials value based on cost.	GBPR.2	
			Reducing overall material use by: (1) using standard assemblies and reducing customised spaces, (2) using materials that do not need finishing, or (3) using materials that possess high durability and require low maintenance.	GBPR.3	
			Using alternative building prefabricated elements not less than 10% of the total element quantity.	GBPR.4	
			Using environment – friendly, sound and thermal insulation materials which have specific requirements as follows: (1) free from chlorofluorocarbons, (2) does not release toxic fumes when burned, (3) the percentage of volatile organic compound is less than 0.1, and (4) thermal insulation materials should have ozone-depleting materials of zero and a low global warming potential which does not exceed 5.	GBPR.5	
Legislation (LG)		IDV	Local governments are authorised to involve CDWM in the permits needed for construction activities. These laws also authorise local governments to gather fees from contractors and owners to provide or pay for CDW collection and disposal.	LG.1	(Zaki and Khial 2014)
			When carrying out exploration, digging construction, or demolition work, or while transporting waste substances or soil, all bodies and individuals shall take necessary precautions to store or transport this waste in a safe way to prevent it from being dispersed.	LG.2	
Awareness (AW)		IDV	Promoting public awareness campaigns SW and its negative impacts.	AW.1	(United Nations Environment Programme (UNEP)) 2009; El-Sherbiny et al. 2011; Zafar 2016; Aden 2017)
			Encouraging cooperation between the public, service providers, and government officials to participate in SWM activities.	AW.2	
			Increasing the awareness about SWM at the workplace.	AW.3	
Culture & behaviour (CB)		IDV	Fostering WR via financial incentives to encourage municipalities and industry practitioners to act.	CB.1	(UNEP 2009; El-Sherbiny et al. 2011; Zafar 2016; Nassour et al. 2016;

(*continued*)

Table 1. Continued.

Construct (i.e. variable)	Type	Indicator (i.e. item)	Code	References
		Establishing educational content about SWM in schools' curriculum.	CB.2	Aden 2017; Arif and Abaza 2012)
		Implementing training and educational programmes about SWM and governance, including officials from central and regional governments.	CB.3	
		Arranging information exchange trips for SW officials to share their experiences and knowledge, improve policies, and learn about new green techniques and practices.	CB.4	
		Implementing SWM educational and research programmes at universities.	CB.5	
Construction and demolition waste reduction (CDWR)	DV	Reducing unnecessary wasted project cost and eliminate project cost overruns.	CDWR.1	(Hussin et al. 2013; Caldas et al. 2014; Memon et al. 2015)
		Delivering the project within the specified schedule with minimal possible delays.	CDWR.2	
		Delivering the project according to the desired quality and specifications.	CDWR.3	

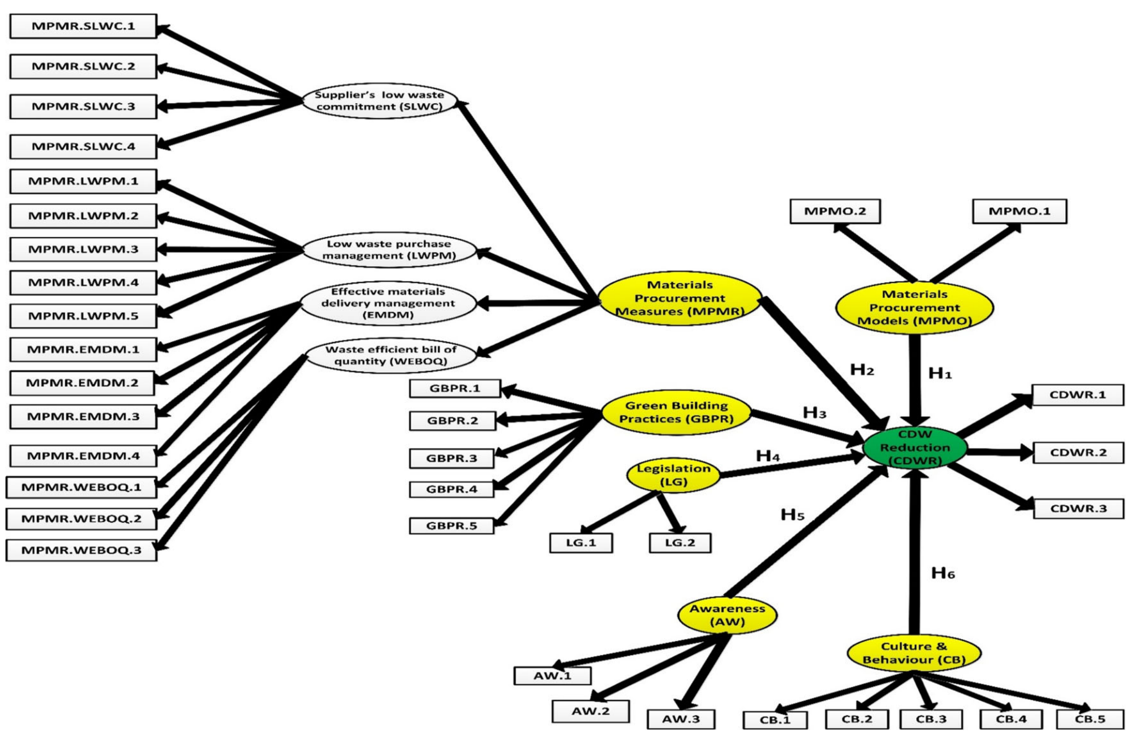

Figure 1. The theoretical framework of the study.

companies as active members (Sada Elbalad 2018). These firms are classified into seven grades based on eight main criteria as follows: (1) invested financial capital; (2) contractor's years of experience; (3) number of technical staff; (4) financial structure; (5) administrative and legal structure; (6) the highest value of the work carried out during the last five years; (7) the value of the largest operation completed during the five years before the submission of the upgrade application; and (8) the upper limit of the allowable value of the tender (El Ehwany 2009; Egyptian Federation for Construction and Building Contractors (EFCBC 2017). Grades one, two, and three are considered 'large firms', grades four and five are considered 'medium firms', and grades six and seven are considered 'small firms' (El Ehwany 2009). According to El Ehwany (El Ehwany 2009), more than 80% of the registered firms belong to the sixth and seventh grades. This statistic means that most Egyptian construction firms are small-sized ones that carry out small-scale and simple construction activities and depend mainly on the workforce more than advanced construction techniques.

In this study, the population considered for sample size calculation was the construction firms registered at EFCBC and located in Greater Cairo (GC). GC was chosen as the central area of investigation for this study for the following reasons: (1) it includes all similarities and contradictions; (2) diversity in levels of education; (3) large number of construction projects; (4) it is political, financial, commercial, and administrative governance; and (5) it includes more than 60% of Egypt's CDW (Hany and Dulaimi 2014). According to the data provided by EFCBC (Egyptian Federation for Construction and Building Contractors (EFCBC 2019), it was indicated that GC includes 1400 construction firms with different grades, as summarised in Table 3.

First, the representative sample size was calculated from the total population (i.e. 1400 construction firms) in GC using a

Table 2. Profiles of the participants in the pilot study.

Respondent	Position	Years of Experience
1	Assistant professor	11
2	Assistant professor	13
3	Associate professor	16
4	Professor	20
5	Professor	22
6	Professor	26
7	Professor	28
8	Professor	25
9	Associate professor	15
10	Associate professor	13
11	Associate professor	18
12	Assistant professor	11
13	Assistant professor	10
14	Assistant professor	12
15	Assistant professor	14
16	Project manager	25
17	Project manager	23
18	Procurement manager	18
19	Civil engineer	14
20	Architect	10
21	Construction manager	15
22	Construction manager	20
23	Architect	12
24	Civil engineer	12
25	Project manager	27
26	Construction manager	17
27	Project manager	21
28	Procurement manager	29
29	Procurement manager	32
30	Architect	15

Table 3. Number of different construction firms in Greater Cairo.

Classification of Firms	Number of Firms
1st-grade	79
2nd-grade	57
3rd-grade	62
4th-grade	154
5th-grade	161
6th-grade	100
7th-grade	787

sample size calculator provided by SurveyMonkey©. This calculator needs three inputs to calculate the sample size as follows: (1) population; (2) confidence level %; and (3) margin of error (i.e. confidence interval) %. The margin of error is a percentage that indicates how much higher or lower it can be expected that the survey results (i.e. sample mean) compared to the actual views (i.e. mean) of the population. The confidence level is a percentage that represents how confident the researcher can be that the population would choose an answer within the confidence interval (Smith 2013). Based on a study carried out by Conroy (2006), 95% is the most recommended confidence level in survey research. Also, it was recommended to adopt a confidence interval between 5% and 10%. Accordingly, this research adopted a confidence level of 95% and a confidence interval of 7.5%, leading to a sample size equal to 153 firms approximately.

Second, stratified random sampling was done for the seven grades to determine the number of companies to be chosen from each category of the total sample size (i.e. 153 firms). The main advantages of stratified sampling are as follows: (1) decreasing the occurrence of bias in the selection of cases to be involved in the sample, and this means that the sample will be highly representative to the population under investigation; (2) permitting the generalisation (i.e. statistical inferences) from the sample to the population because the cases chosen to be involved in the sample are selected based on probabilistic methods, and this is a tremendous advantage as such generalisation seems to have external validity; and (3) ensuring the involvement of sufficient sample points to help in a separate analysis of any strata (Sharma 2017; Stat Trek 2018). Equation 1 calculates the sample size for each stratum (i.e. grade) as follows:

$$\boldsymbol{Stratum\ sample\ size} = \frac{size\ of\ entire\ sample}{\text{population size}}\ X\ stratum\ size \tag{1}$$

The stratified sample size for each stratum is summarised in Table 4. Finally, simple random sampling was done using random numbers using Microsoft Excel 2016© software to randomly choose the number of companies from each grade resulting from the stratified sampling.

Results and discussions

The quantitative analysis of the collected responses from the survey questionnaire was carried out using descriptive and inferential statistical analysis via SPSS V26© software. Descriptive statistics (e.g. mean, frequency, standard deviation, cross-tabulation, and relative importance index (RII)) is useful in describing, summarising, and visualising collected data in numerical and graphical formats to show different patterns coming out from the data (Sutanapong and Louangrath 2015). It helps understand the data's nature in a meaningful way with simple interpretations before proceeding to statistical modelling using multivariate techniques. Descriptive statistics were used to determine respondents' demographic information, the perspectives towards the CDW problem in Egypt, and ranking the different factors affecting CDWR based on their applicability and effectiveness. RII analysis was carried out using Microsoft Excel 2016© software to develop an excel sheet, including the formula of RII, to rank the different factors.

On the other hand, inferential statistics (e.g. correlation analysis) help make predictions or inferences from the collected data, which helps reach conclusions about the relationships between different separated variables from the collectweed data and generalising them to general conditions (Sutanapong and Louangrath 2015). Bivariate correlation analysis was carried out twoe examine the relationships between the different factors (i.e. IDVs) and CDWR (i.e. DV). This step is a matter of checking the significance of the cause-effect relationship between each IDV and DV without being affected by any other surrounding variable (i.e. IDV).

Demographic information

This sub-section presents the demographics of respondents. The respondents have different years of work experiences ranging between '0 to 5 years' and 'more than 20 years'. Most of the respondents, about 77% of respondents, have experiences of '0 to 5 years' and '5 to 10 years'. This may indicate that younger generations are more ambitious and curious about solving the CDW problem in the Egyptian construction industry. Regarding the department at which the respondent is working; 53% of respondents were in the project management department, 16% of respondents were in the procurement management department, and 31% of respondents were in other departments such as the technical office, contracts department, QA/QC department, and operations department. Regarding the highest degree or level of education the respondent had completed; 57% of respondents

Table 4. Stratified sampling of construction firms in Greater Cairo.

Classification of Firms	Stratified Sample Size
1st-grade	9
2nd-grade	7
3rd-grade	7
4th-grade	17
5th-grade	18
6th-grade	11
7th-grade	87

had a bachelor's degree, 8% of respondents had a postgraduate diploma, 24% of respondents had a master's degree, and 11% of respondents had a doctorate. This indicates that a high percentage of the respondents, about 43% of respondents, are highly educated and holders of postgraduate diploma, master's degree, and a doctorate in civil and architectural engineering.

General perceptions and attitudes towards CDW problem in Egypt

The participants answered a specific question which is 'to what extent do you agree that efficient practices, legislation, culture & behaviour and awareness positively affect CDW minimisation?'. 48% of respondents chose 'agree', while 52% of respondents chose 'strongly agree'. This result demonstrates the initial consensus on the hypothesised theory that efficient practices, legislation, culture & behaviour, and awareness can reduce CDW in Egypt.

Also, the participants were asked 'to what extent do you agree that the Egyptian construction industry needs a framework for improving current practices, legislation, culture & behaviour, and awareness in order to minimise CDW?'. 57% of respondents chose 'agree', while 43% of respondents chose 'strongly agree'. This demonstrates that the research motive and objectives are on the right track given the full consensus on the necessity of developing a framework to improve the current practices, legislation, culture & behaviour, and awareness for reducing CDW in Egypt.

Moreover, the participants were asked 'how often do the procurement management and/or project management departments in your firm tend to reduce CDW during projects execution?'. 11% of respondents chose 'never', 21% of respondents chose 'rarely', 38% of respondents chose 'sometimes', and 31% of respondents chose 'often'. This result demonstrates that about 70% of the respondents' firms do not pay careful attention to CDWR given the lack of efficient practices, legislation, culture & behaviour, and awareness in Egypt.

Applicability and effectiveness of different factors affecting CDWR

In this subsection, descriptive statistical analysis is carried out to determine the mean of responses towards evaluating the items (i.e. indicators) of different factors (i.e. IDVs) contributing to CDWR. These items were evaluated on five-point Likert scales based on their current level of applicability in the Egyptian construction sector and their level of effectiveness in solving the CDW problem in Egypt according to respondents' perspectives. Accordingly, these items were accorded two evaluation codes in which a code is used to represent the evaluation of the item based on its applicability level (e.g. MPMO.AP.1), and the other code is used to represent the evaluation of the item based on its effectiveness level (e.g. MPMO.EF.1). First, mean and standard deviation were calculated for the applicability and effectiveness

Table 5. Importance levels.

Importance Levels	Abbreviation	Range
High	H	$0.8 < \text{RII} < 1.0$
High–Medium	H–M	$0.6 < \text{RII} < 0.8$
Medium	M	$0.4 < \text{RII} < 0.6$
Medium–Low	M–L	$0.2 < \text{RII} < 0.4$
Low	L	$0.0 < \text{RII} < 0.2$

levels of the different items. Second, the RII was calculated to rank and rearrange the different items under investigation (Holt 2014).

Items were ranked once based on their applicability levels and another time based on their effectiveness levels. For instance, Enshassi and Saleh (2019) used RII for ranking different lean construction techniques used in reducing accidents in construction projects based on their applicability levels. Also, Mendis et al. (2017) used RII for ranking different associated practices of a safe working cycle (SWC) in the Sri Lankan construction industry based on their applicability levels. On the other hand, Othman et al. (2005) used RII for ranking different factors that drive brief development in the construction industry based on their influence (i.e. effectiveness) levels. RII is calculated using Equation 2 as early investigated by Olomolaiye et al. (1987) and Shash (1993):

$$\mathbf{RII} = \frac{\sum W}{\text{AN}} \tag{2}$$

Where 'W' represents the weights accorded to each item based on its applicability or effectiveness. It ranges from 1 to 5, where 1 = not applied at all or not effective at all, and 5 = extremely applied or extremely effective. 'A represents the highest weight in the rating scales (i.e. five in this study). 'N' represents the total number of engaged respondents (Kometa and Olomolaiye 1997). RII value ranges from zero to one. In this study, high RII values indicate that some items are more applicable or more effective than those with relatively lower RIIs. According to Chen et al. (2010), the ranking importance levels resulting from the RII analysis are derived as investigated in Table 5 as follows:

The results of RII are reported in Table 6, along with the corresponding ranking and their importance level based on the items' applicability levels. It is obvious from the ranking table that most of the items (i.e. 25 items) were identified with 'Medium' and 'Medium-Low' importance levels, while the rest of the items (i.e. eight items) were identified with 'High' and 'High-Medium' importance levels. This indicates that most of the items are not efficiently applied in the Egyptian construction sector and that the Egyptian construction firms are reluctant towards CDWR. These items of 'Medium' and 'Medium-Low' importance levels have RIIs range of 0.597–0.293. The items of 'High' and 'High-Medium' importance levels have RIIs range of 0.911–0.602. Overall, the most applied item among different factors is 'MPMR.LWPM.AP.5' (i.e. correct materials purchase), and the least applied item among different factors is 'LG.AP.2' (i.e. Article 39 of the Egyptian Environment Law 4/1994 and Article 41 of the executive regulations for the Egyptian Environment Law 4/1994).

On the other hand, the results of RII are reported in Table 7, along with the corresponding ranking and their importance level based on the items' effectiveness levels. It is obvious from the ranking table that all the items were identified with 'High' importance levels, except only one item (i.e. MPMO.EF.1), which was identified with a 'High-Medium' importance level. This indicates that almost all items are considered of prime effectiveness for reducing CDW generation even though being not efficiently

Table 6. Descriptive statistics and ranking of different items based on applicability levels.

Construct		Item	Mean	SD	RII	Ranking by Category	Overall Ranking	Importance Level
MPMO		MPMO.AP.1	3.098	0.659	0.620	1	5	H–M
		MPMO.AP.2	2.557	0.498	0.511	2	17	M
MPMR	SLWC	MPMR.SLWC.AP.1	2.984	0.726	0.597	2	8	M
		MPMR.SLWC.AP.2	2.107	0.809	0.421	3	22	M
		MPMR.SLWC.AP.3	4.074	0.761	0.815	1	3	H
		MPMR.SLWC.AP.4	1.541	0.499	0.308	4	28	M–L
	LWPM	MPMR.LWPM.AP.1	2.057	0.784	0.411	4	24	M
		MPMR.LWPM.AP.2	1.648	0.479	0.330	5	27	M–L
		MPMR.LWPM.AP.3	4.041	0.763	0.808	2	4	H
		MPMR.LWPM.AP.4	2.730	0.445	0.546	3	10	M
		MPMR.LWPM.AP.5	4.557	0.498	0.911	1	1	H
	EMDM	MPMR.EMDM.AP.1	2.041	0.785	0.408	3	25	M
		MPMR.EMDM.AP.2	3.008	0.775	0.602	1	7	H–M
		MPMR.EMDM.AP.3	2.713	0.453	0.543	2	12	M
		MPMR.EMDM.AP.4	1.721	0.449	0.344	4	26	M–L
	WEBOQ	MPMR.WEBOQ.AP.1	4.525	0.500	0.905	1	2	H
		MPMR.WEBOQ.AP.2	3.016	0.770	0.603	2	6	H–M
		MPMR.WEBOQ.AP.3	2.730	0.445	0.546	3	10	M
GBPR		GBPR.AP.1	2.582	0.701	0.516	5	16	M
		GBPR.AP.2	2.779	0.416	0.556	2	9	M
		GBPR.AP.3	2.615	0.672	0.523	3	14	M
		GBPR.AP.4	2.598	0.662	0.520	4	15	M
		GBPR.AP.5	3.008	0.622	0.602	1	7	H–M
LG		LG.AP.1	2.234	0.424	0.447	1	21	M
		LG.AP.2	1.467	0.500	0.293	2	29	M–L
AW		AW.AP.1	2.721	0.449	0.544	2	11	M
		AW.AP.2	2.697	0.461	0.539	3	13	M
		AW.AP.3	2.730	0.445	0.546	1	10	M
CB		CB.AP.1	1.721	0.449	0.344	5	26	M–L
		CB.AP.2	2.516	0.501	0.503	2	19	M
		CB.AP.3	2.090	0.791	0.418	4	23	M
		CB.AP.4	2.541	0.499	0.508	1	18	M
		CB.AP.5	2.500	0.501	0.500	3	20	M

Table 7. Descriptive statistics and ranking of different items based on effectiveness levels.

Construct		Item	Mean	SD	RII	Ranking by Category	Overall Ranking	Importance Level
MPMO		MPMO.EF.1	3.988	0.872	0.798	2	29	H-M
		MPMO.EF.2	4.061	0.842	0.812	1	26	H
MPMR	SLWC	MPMR.SLWC.EF.1	4.299	0.804	0.860	4	19	H
		MPMR.SLWC.EF.2	4.398	0.710	0.880	1	15	H
		MPMR.SLWC.EF.3	4.357	0.770	0.871	3	17	H
		MPMR.SLWC.EF.4	4.391	0.766	0.878	2	16	H
	LWPM	MPMR.LWPM.EF.1	4.549	0.698	0.910	1	8	H
		MPMR.LWPM.EF.2	4.516	0.728	0.903	4	11	H
		MPMR.LWPM.EF.3	4.520	0.740	0.904	3	10	H
		MPMR.LWPM.EF.4	4.533	0.699	0.907	2	9	H
		MPMR.LWPM.EF.5	4.504	0.729	0.901	5	12	H
	EMDM	MPMR.EMDM.EF.1	4.160	0.997	0.832	3	23	H
		MPMR.EMDM.EF.2	4.152	0.959	0.830	4	24	H
		MPMR.EMDM.EF.3	4.193	0.916	0.839	1	20	H
		MPMR.EMDM.EF.4	4.164	0.942	0.833	2	22	H
	WEBOQ	MPMR.WEBOQ.EF.1	4.418	0.665	0.884	2	14	H
		MPMR.WEBOQ.EF.2	4.467	0.693	0.893	1	13	H
		MPMR.WEBOQ.EF.3	4.332	0.754	0.866	3	18	H
GBPR		GBPR.EF.1	4.654	0.752	0.931	4	6	H
		GBPR.EF.2	4.687	0.711	0.937	3	5	H
		GBPR.EF.3	4.807	0.537	0.961	1	1	H
		GBPR.EF.4	4.725	0.687	0.945	2	3	H
		GBPR.EF.5	4.520	0.927	0.904	5	10	H
LG		LG.EF.1	4.180	0.754	0.836	1	21	H
		LG.EF.2	4.061	0.791	0.812	2	26	H
AW		AW.EF.1	4.730	0.552	0.946	1	2	H
		AW.EF.2	4.635	0.722	0.927	3	7	H
		AW.EF.3	4.697	0.684	0.939	2	4	H
CB		CB.EF.1	4.086	0.613	0.817	1	25	H
		CB.EF.2	4.057	0.706	0.811	3	27	H
		CB.EF.3	4.053	0.738	0.811	4	28	H
		CB.EF.4	4.061	0.817	0.812	2	26	H
		CB.EF.5	4.086	0.829	0.817	1	25	H

Table 8. Descriptive Statistics and Bivariate Correlations among Variables.

	MPMO	MPMR	GBPR	LG	AW	CB	CDWR
MPMO	1	0.313***	0.335***	0.020	0.467***	0.649***	0.533***
		0.000	0.000	0.751	0.000	0.000	0.000
MPMR		1	0.361***	0.021	0.515***	0.367***	0.452***
			0.000	0.749	0.000	0.000	0.000
GBPR			1	−0.099	0.528***	0.380***	0.509***
				0.124	0.000	0.000	0.000
LG				1	−0.008	0.072	0.086
					0.904	0.263	0.183
AW					1	0.467***	0.566***
						0.000	0.000
CB						1	0.563***
							0.000
CDWR							1
Mean	4.0246	4.3648	4.6787	4.1209	4.6872	4.0689	4.0594
SD	0.78529	0.55914	0.53223	0.71199	0.57619	0.592	0.647

*$P < 0.05$,
**$P < 0.01$,
***$P < 0.001$

applied in Egypt. These items of 'High' importance levels have RIIs in the range of 0.961–0.811. The item of 'High-Medium' importance level has an RII of 0.798. Overall, the most effective item among different factors is 'GBPR.EF.3' (i.e. reducing overall material use by using prefabricated elements and highly durable materials), and the least effective item among different factors is 'MPMO.EF.1' (i.e. SCPM).

Examination of relationships – bivariate correlation between independent and dependent variables

In this subsection, the relationships between IDVs and DV are investigated through correlation analysis. An examination of the effect of each IDV on the DV was carried out to indicate what are the strongest and weakest variables' associations as a matter of checking the internal validity of the cause-effect proposed model (Mitchell 1985). Internal validity check helps determine the degree of confidence that the investigated model's cause-effect relationships are trustworthy and not affected by any other surrounding variables. In this correlation analysis, IDVs are represented by the level of effectiveness, while DV is represented by the level of agreement on reaching targeted outcomes of CDWR. The Pearson product-moment correlation coefficient (r) was calculated to determine the strength of the relationships and the effect of each IDV on the DV (Zhang et al. 2019). Pearson correlation gives an indication of both directions (i.e. positive or negative) and the strength of a relationship (i.e. weak, moderate, strong) between two variables (Field 2009). A positive correlation means that if one variable increases, then the other variable will also increase, while a negative correlation means that if one variable increases, the other variable will decrease (Norusis 2004; Pallant 2010).

The values of r range from -1 (i.e. perfect negative correlation) to $+1$ (i.e. perfect positive correlation). Accordingly, the following values of r determine the strength of the relationship between the variables: 0.00 means no linear relationship; 0.01–0.30 means a weak relationship; 0.31–0.70 means a moderate relationship; 0.71–1.00 means a strong relationship; and 1.00 means a perfect linear relationship (Ratner 2009). Values of r were used to examine the association of CDWR with MPMO, MPMR, GBPR, LG, AW, and CB. The values of r were reported altogether with significance level values (i.e. P-values) to determine whether a relationship is significant or not. Suppose P-value is below 5% (i.e. 0.05). In that case, this means that there is sufficient evidence to reject the null hypothesis H_0 (i.e. there is no relationship existing between the IDV and DV) in favour of the alternative hypothesis H_n (i.e. there is a positive linear relationship existing between the IDV and DV).

Table 8 shows the correlation analysis results (i.e. r and P values) and descriptive statistics (i.e. mean and standard deviation) of the IDVs and DV. It shows a matrix of r (i.e. first row) and P (i.e. second row) values corresponding to each variable. The r and P values demonstrate significant positive relationships among the DV and IDVs except 'LG'. There is a statistically significant moderate positive relationship between MPMO and CDWR, in which $r(244) = 0.533$ and $P < 0.001$. Also, there is a statistically significant moderate positive relationship between MPMR and CDWR, in which $r(244) = 0.452$ and $P < 0.001$. Moreover, there is a statistically significant moderate positive relationship between GBPR and CDWR, in which $r(244) = 0.509$ and $P < 0.001$. Additionally, there is a statistically significant moderate positive relationship between AW and CDWR, in which $r(244) = 0.566$ and $P < 0.001$. Furthermore, there is a statistically significant moderate positive relationship between CB and CDWR, in which $r(244) = 0.563$ and $P < 0.001$. In contrast, there is a statistically non-significant weak positive relationship between LG and CDWR, in which $r(244) = 0.086$ and $P = 0.183$. The P-value exceeds 0.05; accordingly, there is no evidence to reject the null hypothesis H_0 in favour of the alternative proposed hypothesis H_4 here.

The non-significant relationship between 'LG' and 'CDWR' can be demonstrated by the responses of participants towards the following question: to what extent do you agree on the following statement 'the Egyptian legislation lack effective waste minimisation strategies and they only focus on waste transfer, charge, and dumping'? 50.8% of the respondents strongly agreed and 49.2% of the respondents agreed, which shows that the Egyptian legislation are not fully effective in reducing CDWG efficiently. Egyptian legislation only focus on CDW collection, transfer, and disposal without encouraging the adoption of reduction technique or any other technique of the 4Rs techniques (Daoud et al. 2020b). Egyptian CDWM legislation can be better improved by including guidance for adopting waste-efficient materials procurement practices to foster CDWR and apply incentives to adopt them.

Conclusions and recommendations

CDW is one of the global challenges which threaten developed and developing nations. It contributes up to 50% of the total global annual generated SW, and it represents approximately 10% of the total cost of materials used in construction projects. In Egypt, the problem is serious, in which CDW represent up to 40% of total materials cost in construction projects. Moreover, the dominant practice of handling CDW in Egypt is illegal dumping which negatively affects society and the environment. This indicates the negative impact of CDW on sustainable development in Egypt. According to different studies, it has been found that there are different factors compiled under six main factors which may help in CDWR as follows: (1) waste-efficient materials procurement measures; (2) waste-efficient materials procurement models; (3) green materials procurement approach of green building (GB) practices; (4) legislation; (5) culture & behaviour measures; and (6) awareness measures. These factors are considered as the IDVs which affect the DV, namely 'CDWR'.

This study provides a new contribution to knowledge through a quantitative research approach using a survey questionnaire which helped in (1) determining the perceptions and attitudes towards CDW problem in Egypt; (2) ranking the different IDVs based on their effectiveness and applicability in the Egyptian construction sector; and (3) examining the relationships between the different IDVs and the DV. Through the descriptive statistical analysis, demographic information of respondents and their firms were investigated. Given the participants' responses, there was a consensus among the respondents that efficient practices, legislation, culture & behaviour, and awareness can help reduce CDW in Egypt. The respondents also pointed out the need to develop a framework that can integrate all these factors for reducing CDW in Egypt. Besides, the respondents agreed that Egyptian CDWM legislation are ineffective in reducing CDWG efficiently because they do not foster CDWR. Unfortunately, the responses showed that most respondents' firms do not care for reducing CDW as they do not efficiently apply the abovementioned factors, which can greatly help CDWR.

Based on the RII formula, the different CDWR factors were ranked based on their current applicability level in the Egyptian construction sector and their level of effectiveness towards CDWR. It was found that 'correct materials purchase' is the most applied item among the different factors, while the most effective item among different factors is 'reducing overall material use by using prefabricated elements and highly durable materials'. Finally, correlation analysis was carried out to investigate the cause-effect relationship between each IDV and the DV. It was found that there are significant positive relationships between the DV and all IDVs except 'LG'. This demonstrates that Egyptian legislation are not fully effective solely in reducing CDWG. The next step of this research recommends carrying out a multivariate statistical analysis of the survey questionnaire's responses using the structural equation modelling (SEM) technique. This is helpful to test and validate the theoretical framework of different hypotheses and different factors in a multiple system in favour of developing a conceptual framework for minimising CDW in the Egyptian construction sector.

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