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Empirical Evidence from Egypt on an Integrated Framework for Reducing Construction Waste

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Research Article
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Abstract
Construction and demolition waste (C&DW) is a major problem in the construction industry since it is produced at different stages of a project. The issue that this waste has caused is widespread, ever-present, and will remain for a long time. This study used a quantitative method in two phases to assess the problem and provide workable answers. In the first phase, 360 construction organisations in Egypt were randomly chosen to participate in an online survey that assessed the effect of six primary variables on C&DW reduction (C&DWR). Here are the six primary factors: law (LG), green building practices (GBPR), materials procurement models (MPMO), green building measures (MPMR), culture and behaviour (CB), and awareness (AW). In order to aid Egypt's vision 2030, the second phase included creating a unified framework for C&DWR using multivariate statistical analysis using the structural equation modelling (SEM) method. According to the findings, C&DWR in Egypt are favourably impacted by these six variables. The research also showed that GBPR has the best performance rate at 92.169 and the greatest importance value at 0.293. Of the six criteria, CB's performance is the worst at 72.08, but its significance value is 0.238, making it the second most important. In line with Egypt's Vision 2030, this document offers concrete suggestions on how the government and the construction industry can lessen the C&DW.

Keywords Construction and demolition waste · Waste reduction · Built environment · Sustainability · Structural equation modelling · Egypt

1 Introduction

When it comes to social and economic progress, the building industry is among the most important since it improves people's quality of life [1, 2]. Building roads, hospitals, schools, and colleges are all part of this broader socioeconomic agenda. It should come as no surprise that C&DW is rapidly becoming an issue on a worldwide scale [3]. All things considered, the Solid waste (SW) production will rise from 1.3 billion metric tonnes in 2015 to 2.2 billion metric tonnes in 2025, according to the World Bank. More than half of the world's SW per year comes from C&DW [5, 6]. A 2017 report from Transparency Market Research indicates that C&DW production will rise significantly going forward [6]. Indeed, there is a widespread problem with improperly disposing of C&DW, which has negative consequences for both society and the environment [7, 8]. Without a doubt, the majority of countries in the MENA region, including Egypt, use stochastic disposal methods for dealing with C&DW [9–14].

U.N. Environment Programme officials Most landfills are dangerous and don't have enough safety measures to stop trash from setting itself on fire and polluting the environment, according to studies [9] and Memon et al. [15]. Thus, biodegradation of C&DW in landfills causes major problems with human and environmental health [16–18]. These acts of unlawful dumping have worsened the solid waste issue, which had devastating effects on the economy, society, and the environment—

the three pillars of sustainability known as the triple bottom line (TBL) [9–14, 19]. Resolving this scenario in the MENA region requires prompt action on C&DW concerns. Inadequate management of construction waste is a significant difficulty for all industries, including Egypt's construction sector [20]. The cost of construction and demolition work (C&DW) should not go beyond four percent of the whole material cost, says Shamseldin [21]. Unexpectedly, significant projects in Egypt account for around 16% of overall building expenses, while 40% of all construction materials go to waste [21].

Without a doubt, the effectiveness, efficiency, value, and profitability of the construction sector are negatively affected by insufficient C&DW management (C&DWM) [22]. In this regard, Memon et al. [15], Park et al. [23], and Jalaei et al. [24] have asserted that the C&DW lowers the sustainability TBL and hurts the national economy. Caldas et al. [25] states that between half and three quarters of a project's budget goes towards the cost of materials and equipment used in construction. These two categories are interdependent and have a major influence on eighty percent of the project's timeline. In their comprehensive study of C&DW issues in Egypt, Daoud et al. [26–31] identified many causes for the decline in C&DW in that country. The theoretical framework developed in this study is based on these elements. Six main elements, with a number of sub-factors, were determined to be crucial to the suggested sustainable framework solution in the conducted extensive literature research. Awareness (AW), culture and behaviour (CB), green building practices (GBPR), materials procurement models (MPMO), legislation (LG), and first-and-second-guess (MPMR) are the six elements [26–31].

Research on C&DWM in the last several decades has focused mostly on methods for reducing waste during the design and construction stages, but has paid less attention to methods for reducing waste during the materials procurement stage [32]. The term "materials procurement" was used by Zeb et al. (2015) [33] to describe the process of acquiring the various items required to carry out a project. Purchasing and arranging for the delivery of goods to vendors are both aspects of procurement. When it comes to acquiring building supplies that meet high requirements in terms of quantity, quality, price, location, and time, Kamalaeaswari and Vedhajanani (2015) [28] state that material acquisition and delivery scheduling is crucial. Inefficient materials procurement is a major contributor to C&DW generation (C&DWG), which in turn affects the total cost of the project [34, 35]. According to Ajayi et al. (2017a) [32], 50% of the projects are affected by material procurement.
whole amount of the project. Additionally, it was shown by Fadiya et al. (2014) [36] that inefficient material procurement accounts for up to 11.2% of total C&DWG. In order to reduce C&DW (C&DWR) and costs, it is vital to obtain materials in an effective manner. This link is critical between the design and construction stages. Measures and models for materials procurement in C&DWR and the use of green materials contained in GBRSs are examples of waste-efficient practices in materials procurement [26, 27]. None of the aforementioned methods are often used in Egypt's construction sector since "dumping" is the norm and the sole option for dealing with C&DW [11, 16].

In addition, Daoud et al. (2020b) [28] investigated SW and C&DW problems in the MENA region and Egypt in great detail. A number of external factors, including laws, public knowledge, cultural norms, and individual actions, impact C&DWR, alongside waste-efficient materials procurement procedures. When put into place within a C&DWR framework, these elements are critical for lowering C&DW via a series of defined activities. A lack of waste-efficient legislation, an inappropriate culture, inappropriate behaviour, and a lack of awareness of the C&DW issue all contribute to the poor regulation of the Egyptian construction industry, according to Daoud et al. (2020b) [28].

Examining and suggesting the best strategy for reducing C&DW in Egypt's construction sector is the primary goal of this study. This goal will be accomplished by conducting an analysis of the six main causes of construction-related delays (C&DWR) in Egypt's building industry, and by developing a strategy to remove these delays once and for all, in line with Egypt's Vision 2030. Accordingly, the study delves into the research technique that was used to accomplish the aforementioned goals in the part that follows. Research findings are provided to explain the conclusions and findings. And here we see the road plan that is the proposed integrated framework for cutting down on C&DW in Egypt. Discussion of final thoughts and suggestions for the future follows.

2 Research Methodology

In order to help policymakers and the construction industry in Egypt reduce C&DW, it was crucial to thoroughly investigate the cause-and-effect relationship between each of the six factors listed above and C&DWR. This investigation had to take into consideration the unique characteristics of the Egyptian construction industry. business field. The C&DWR is the dependent variable (DV), and these factors have a substantial effect on it; they are independent variables (IDVs). A "DV" refers to the result, whereas a "IDV" describes the cause [37]. The relationship between DV and IDVs is best described as interdependent since the value of IDV affects the value of DV. This is why studying and predicting how IDVs may affect DV is a common area of interest for academics [37]. Also employed to assess and represent IDV and DV are indicators, also called "constructs," which are physical objects. According to Daoud et al. [38], indicators that indicate the same factor should have equal weights and so be unrelated to each other.

Each indication has been given an initial code that will be used later on in the data analysis process. Daoud et al. [31] investigates the IDVs, DV, associated items, and their corresponding codes in greater detail, so that the theoretical framework may be shown directly and proportionally. Here is the theoretical framework shown in Figure 1. In Figure 1, we can see how the six light blue ellipse-shaped parameters contribute to lowering C&DW and how their cause-and-effect connection is shown. Fig. 1 shows that the theoretical framework is made up of six assumptions that need to be tested and confirmed in the Egyptian construction industry. In this study, we will compare the null hypothesis (H0)—that the IDV has no impact on the DV—with the alternative hypothesis (Hn)—that the IDV has a positive effect on the DV. Put simply, the goal is to provide enough proof to dismiss the null hypothesis. supporting the alternative hypothesis Hn over the null hypothesis H0. So, here are the six alternative hypotheses (Hn) that have been proposed:
C&DWR are positively impacted by models that acquire resources in an effective manner.
• H2: C&DWR benefit from waste-efficient materials procurement strategies.
• Hypothesis 3: Green's Sustainable Materials Procurement Strategy

When it comes to C&DWR, building (GB) practices are beneficial.
• Hypothesis 4: The C&DWM Act benefits

The C&DWR sector.
• H5: C&DWR benefit from increased awareness.
• H6: C&DWR are positively impacted by culture and conduct.

A representative sample of Egyptian construction professionals from various levels and specialisations participated in an online survey conducted using Qualtrics. The purpose of the study was to explore the aforementioned cause-and-effect linkages within the Egyptian construction industry. Owners, consultants, supervisors, suppliers, government officials, and others with a direct or indirect stake in the C&DWG were all represented in the sample. Because of its intended purpose in investigating causation, the online survey was selected as the best methodology. Furthermore, according to Saunders et al. [39],

the survey methodology is the best choice for building trustworthy indices and verifiable data from field observations because of its unique properties. A web-based poll is

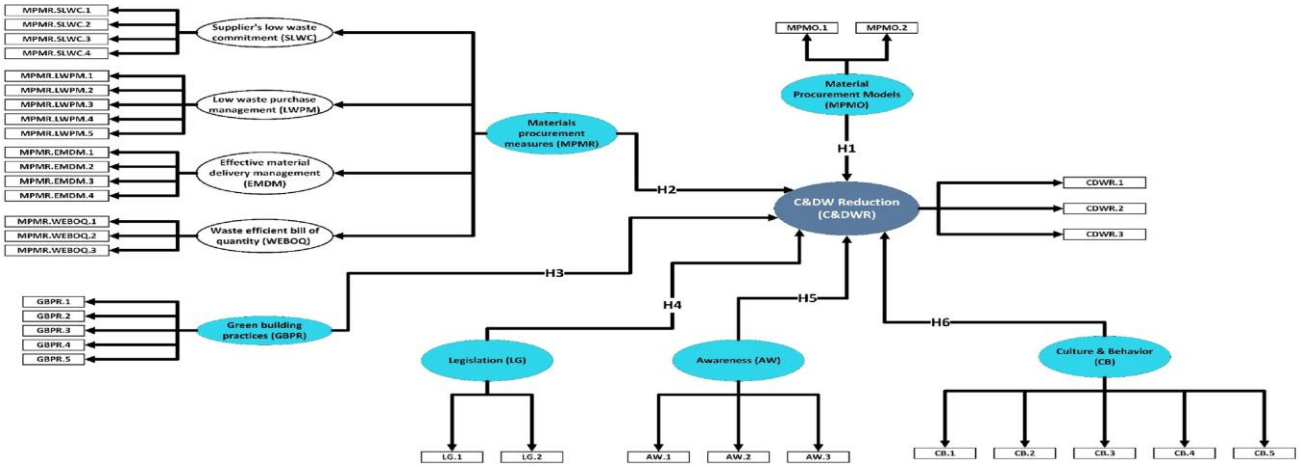


Fig. 1 The theoretical framework of the study

very useful for studying (1) organisational practices, beliefs, and attitudes and (2) correlations between various variables, especially for cause-and-effect interactions [39]. Thus, the chosen method helped gather detailed data using an appropriate sample size, which allowed for a synopsis of the results. Several phases make up the strategy, and they are described in depth in the sections that follow.

The Survey Questionnaire Design (2.1)

Four primary elements made up the online survey. Section one focused on C&DWR evaluations of material procurement models and metrics, as well as green material procurement methods. The second part of the report assessed how well C&DWR laws in Egypt work. Section three assessed how well the C&DWR's cultural and behavioural components worked in tandem with the awareness component. In essence, the purpose of the preceding sections was to examine the aspects and circumstances impacting C&DWR with respect to how well they accomplish C&DWR's aims. The fourth and last segment evaluated the degree of consensus that could be reached on the necessary and anticipated improvement for the several project aspects (i.e., time, quality, and cost) using C&DWR.

In order to make the questionnaire as easy to fill out as possible, we included close-ended questions that used an ordinal scale. The five-point Likert scale was used to quantify the feedback of responders for each topic, based on research by Vagias [40] and Brown [41]. Using a Likert scale where "1" denotes "not effective at all" and "5" means "extremely effective," we evaluated the various factors that contribute to C&DWR as described in the literature studies and theoretical framework. In addition, we used an extra Likert scale to see how much consensus there was on how C&DWR would enhance the project's time, money, and quality (where a score of 1 indicates "strongly disagree" and a score of 5 indicates "strongly agree").

2.2 Test Run

Verifying the validity of the expected answers and the trustworthiness of the selected assessment tool (the Likert scale) was a prerequisite to collecting primary data [42]. Consequently, the survey's readability, simplicity, thoroughness, and practicability were evaluated in a first pilot research [39]. According to Saunders et al. [39], a pilot survey with a minimum sample size of 10 people is considered effective. Therefore, 30 people took part in the pilot study; half of them were specialists and professionals in the field, while the other half were professors with a combined

background of over ten years of experience in the field as well as in teaching and research. Using SPSS V26© software, Cronbach's alpha was computed for the range of variables to assess the consistency and reliability of the data gathered. The results of the pilot survey were more than the cutoff value of 0.70, showing that consistency and dependability are maintained, according to George and Mallery [43].

2.3 Participants Focused on Sample Size

The population, the level of confidence, and the error margin (also known as a confidence interval) were the three variables that were required to determine the sample size. From the population, we calculated that 1,400 construction enterprises in Greater Cairo (GC) made up the representative sample size. According to Conroy [44], a confidence range of 5–10% should be used with a 95% confidence level in survey research. The researchers in this study so settled on a 95% confidence level and a 7.5% confidence interval. Consequently, 153 people should make up the minimum required sample size for this investigation. So, the survey was sent out online to 360 people, and 244 of them responded—which is more than the needed sample size.

3. Discussion and Results

In order to examine the gathered data, the structural equation modelling (SEM) method was used using SmartPLS 3.3.2© software. The theoretical framework, which included six assumptions, was tested using SEM. For the purpose of investigating correlations between IDVs and DVs, the SEM is a generic linear model approach. It is possible to see these variables as latent variables (i.e., constructs) or as measurable variables (i.e., indicators or items) directly [45, 46]. Explaining and validating a given causal theoretical framework is the primary objective of structural equation modelling (SEM). Here are the two phases that make up the SEM's validation procedure:
(1) Confirmatory factor analysis (CFA) is the first stage in verifying the measurement model. It tests the extent to which the measured indicators reflect their relevant constructs.
Step two involves putting the structural model into action and using route analysis to test the study hypotheses.
Research in the fields of social science, psychology, and even building has made use of SEM, according to Xiong et al. [47]. Tenenhaus et al. [49] and Kline et al. [48] demonstrated that the partial For investigations including pragmatic contexts, the most practical technique is the partial least squares (PLS) method of the structural equation model (PLS-SEM). This is mostly because it takes a problem-oriented approach, which seeks to provide actual answers to issues that have been recognised. Compared to CB-SEM and basic least squares regression, PLS-SEM is a more efficient solution.

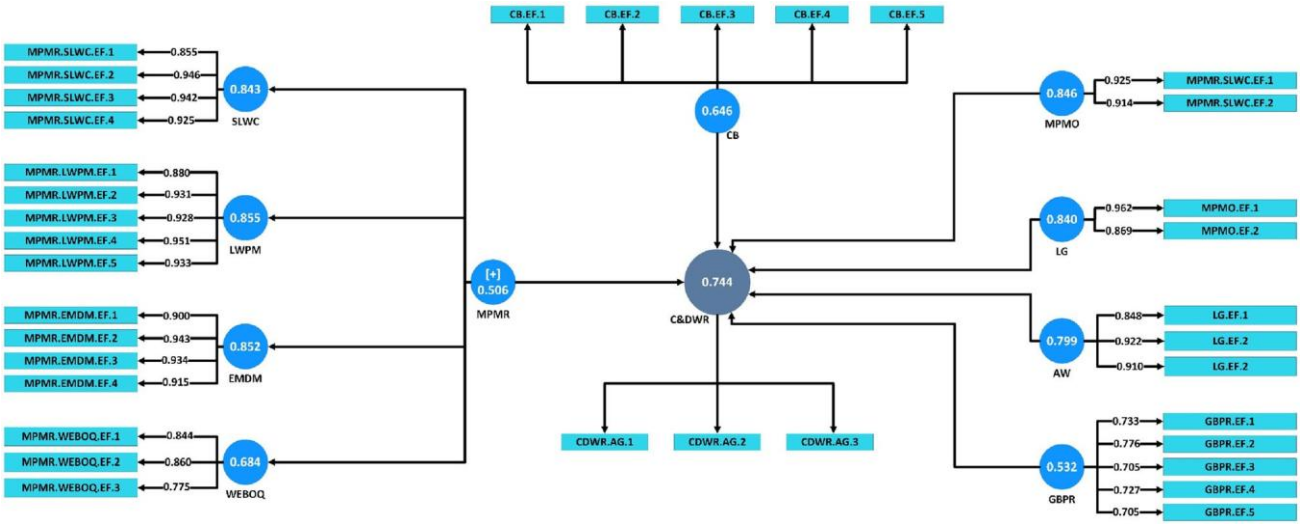


Fig. 2 Outer loadings and AVE for different constructs in the research model

2.1.1 Path Coefficients

Path coefficients are estimates of the relationships between the model's components [62]. According to [52], the coefficients may take on values between + 1 and -1, where + 1 denotes a strong positive correlation, 0 a weak or nonexistent association, and -1 a strong negative correlation. When analysing PLS pathways, it is important to present not only the significance level (a), t value, and P value, but also the path coefficients (b) [67]. The bulk of the studies that used PLS-SEM to investigate the structural model provided path coefficients (b), significance level (a), t value, and P value, according to an analysis by Ringle et al. [66] of articles published in "Management Information Systems (MIS) Quarterly" between 1992 and 2011. The direction and significance levels of the route coefficients should also be considered when assessing the model's quality, according to Chin [70]. Hence, these numbers are used in the route analysis computation. Consequently, a 5% significance threshold (a) was used in this investigation, which means that the t-value must be more than 1.96 and the P-value must be less than 0.05 in order to consider the connection as statistically significant [58]. But, if the t-value is more than 1.96 and the P-value is less than 0.05, it indicates that there is sufficient evidence to reject the null hypothesis H0 (that the IDV does not affect the DV) and support the alternative hypothesis H1. The model's b-values, together with its t-values and P-values, are shown in Table 8 and Fig. 3, respectively. It should be noted that "AW" has a positively and statistically significant effect on C&DWR, with b = 0.188, t = 3.192, and P < 0.001. With b = 0.217, t = 2.963, and P \ 0.01, CB"has a statistically significant positive effect on C&DWR, while "GBPR" has a statistically significant positive effect on C&DWR with b = 0.231, t = 4.069, and P \ 0.001. With b = 0.174, t = 2.357, and P \ 0.05, "MPMO" has a statistically significant positive effect on C&DWR, and with b = 0.152, t = 2.754, and P \ 0.05, "MPMR" also has a statistically significant positive effect on C&DWR. less than 0.01. The positive statistical significance of "LG" is finally established.

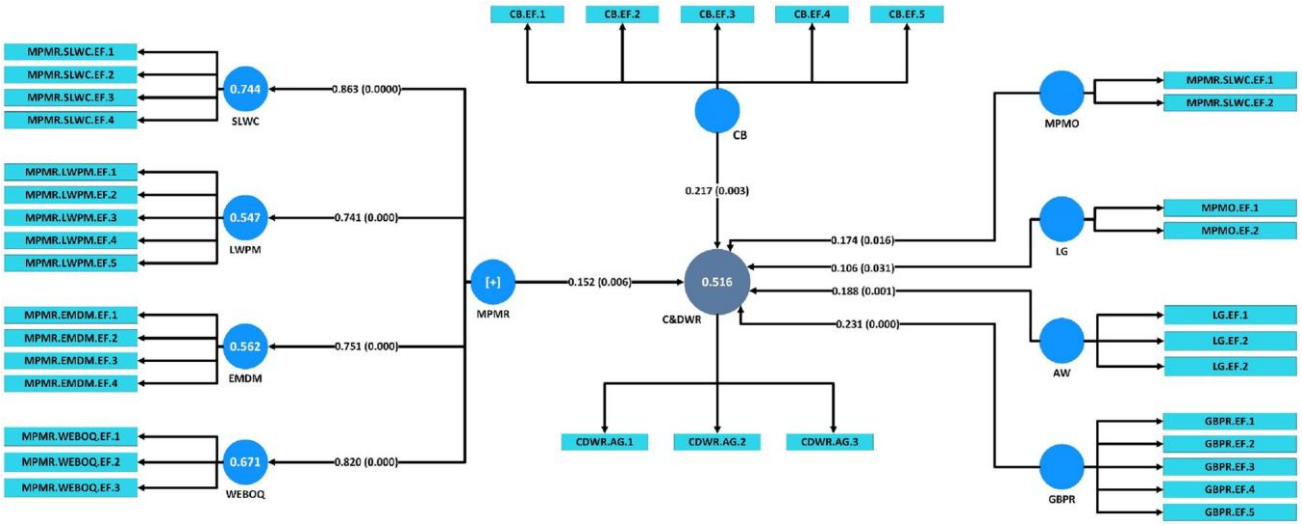


Fig. 3 Path coefficients with corresponding P values and R^2 adj value of DV impact on C&DWR; since b = 0.106, t = 2.037, and P ＼ 0.05. These results indicate robust and sufficient evidence to refute the null hypotheses in favour of all the proposed hypotheses in this study.

2.1.2 Coefficient of Determination (R^2)

As a quality metric for the structural model, coefficient of determination (R2)[67] is associated with the impact of IDVs on the DV [62]. After reviewing 204 studies that used the PLS-SEM, Hair et al. [67] determined that R2 is the main metric for evaluating structural models. In a similar vein, Ringle et al. [66] found that R2 was reported in 105 out of 109 models after reviewing a multitude of studies that used the PLS-SEM in information systems. A low R2 number indicates little explained variation, whereas a high R2 value indicates a great deal of explained variance. Contrary to what Hair et al. [56] said in their marketing study, R2 values of 0.25, 0.50, and 0.75 are considered low, moderate, and high, respectively. However, the value of R2 is controversial. On the other hand, according to Chin [70], R2 values of 0.19, 0.33, and 0.67 are considered poor, moderate, and high, respectively, in the context of business research. Both Hair et al. [58] and Henseler et al. [71] state that researchers should publish the modified R2 values, which take into account the number of IDVs and the sample size. R2 values rise as the number of IDVs increases; however, the R2 adj makes up the difference by considering the model's complexity [58]. In addition, when comparing models in different settings or evaluating their quality, the R2 adj values are crucial [71]. Table 9 and Figure 3 show the findings of the R2 adj. About 52% of the variance in C&DWR may be explained by fluctuations in the IDVs, according to the model's R2 value of 0.528 and its R2 adj value of 0.516.

2.1.3 Effect Size (f^2)

When an exogenous construct (such as IDV) is removed from the model, causing a change in the R2 value of the model, the effect size (f 2) is a measure of the amount by which the endogenous construct will be altered [58]. The SmartPLS© programme is used to calculate the f 2 values. The f 2 value of a construct is categorised as small, medium, or big depending on its range: from 0.02 to 0.15 for minor effects, 0.15 to 0.35 for medium effects, and 0.35 and above for large effects [58]. If a construct's f 2 value is less than 0.02, it indicates that it does not impact the endogenous construct, as stated by Hair et al. [54]. The structures' f 2 effect sizes are shown in Table 10.

According to the findings, each IDV has a negligible impact on the DV. However, the DV will be affected by the elimination of any IDV, which will cause a

significant change in the model's R2 value. In terms of impact magnitude, the "GBPR" is the most IDV-like, while the "LG" is the least IDV-like. In order of impact magnitude, the IDVs are as follows: (1) GBPR, (2) CB, (3) AW, (4) MPMR & MPMO, and (5) LG.

2.1.4 Finding What You Need to Know (Q2)

Q2, or predictive relevance, is a measure of the model's predictive ability when used outside of the sample [58]. Predictive power or predictive relevance refers to a model's ability to correctly foretell outcomes based on data that was not adequately used to estimate those outcomes. A blindfolded procedure is used to determine the Q2 value. Before you can conduct this process, you need to provide an omission Distance (D). Although the sample size divided by the chosen D will not provide an integer, Hair et al. [58] recommended picking a D between 5 and 12, taking into consideration this fact carefully. The blindfolding process will omit and forecast every dth data point of the endogenous construct's items, as indicated by the omission distance. An omission of around 20% of the data points every blindfolding cycle is indicated by a D of 5. Similarly, for each blindfolding cycle, a D of 10 means that about 10% of the data items were excluded. Omission distance D is directly proportional to the blindfolding iteration count. If any data points are missing from the PLS-SEM, the missing values will be handled by either pairwise deletion or mean value replacement. Predicting the missing data points is the next step using the estimated values. The value of Q2 is then determined by subtracting the projected values from the actual values, which includes the deleted data points. A self-contained entity's

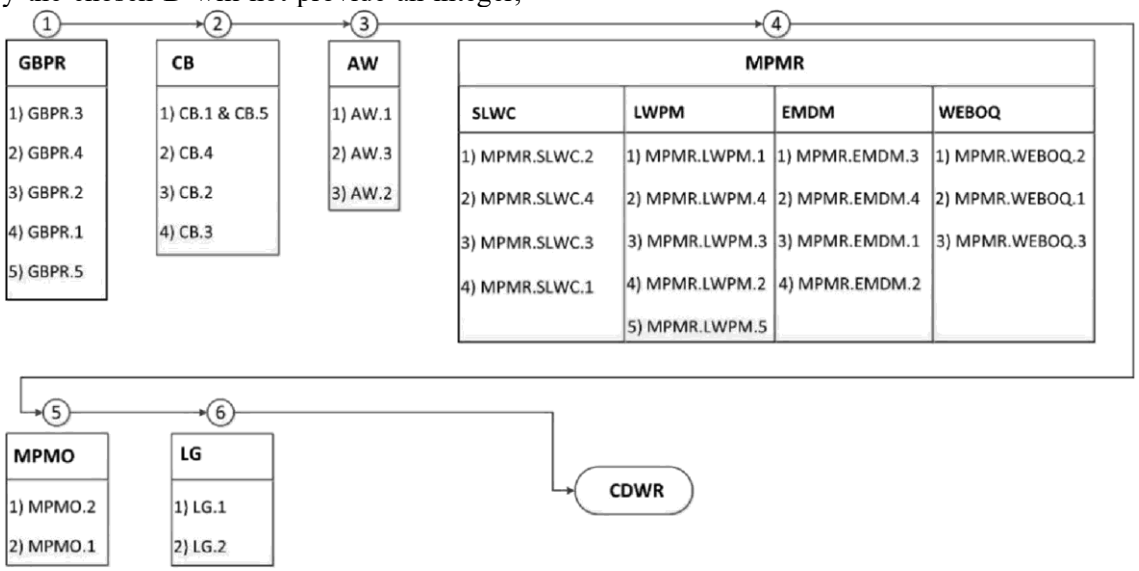


Fig. 4 Roadmap for implementing the integrated framework

3 Roadmap for Implementing the Integrated Framework in the Egyptian Construction Industry

Based on the results of effect size analysis and the importance–performance matrix of the IDVs, and the results of RII analysis for the effectiveness of dif- ferent IDVs components (i.e. items)' the following roadmap is introduced to set and prioritise the application of the different factors along with their various components and measures in a sequential manner. The authors strongly recommend that the policymakers and construction professionals strictly adhere to the proposed roadmap, which undoubtedly will contribute to reducing C&DW in the

construc- tion industry in Egypt. This roadmap arranges the application of the different factors in descending order based on their weightings (i.e. effect size and importance) and the application of their measures and components based on their level of importance resulting from RII analysis of their effectiveness. The different IDVs were arranged in descending order according to their weightings. The roadmap for implementing the integrated framework is sum- marised in Fig. 4. As illustrated in Fig. 4, the six factors' components are listed in descending order based on their RII analysis.

4 Conclusion

Despite the sector's best efforts to implement innovative management practices, the worldwide construction industry is still feeling the effects of the C&DW. According to this research, C&DW constitutes as much as 40% of the total materials expenditures in Egyptian construction projects, making it a major concern for both the government and the industry as a whole. Despite the obvious health risks to humans and ecosystems, Egypt's main approach to C&DW is careless disposal. In light of Egypt's vision 2030, this research proposes an innovative integrated framework to aid policymakers and building industry experts in minimising C&DW and evaluates the effect of six primary elements for C&DWR in Egypt. According to the research, "GBPR" has the most impact on Egypt's C&DW, followed by "LG," "MPMO," and "MPMR," in that order of decreasing impact. Furthermore, the poor performance of the "CB" is inextricably related to the reduction of C&DW in Egypt. In order to get the results that C&DWR want, "CB" means taking swift action. Without a doubt, the decision-makers will be able to easily execute the suggested integrated framework thanks to the created roadmap. In order to drastically reduce C&DW in Egypt, the government and the construction sector would greatly benefit from the suggested strategy.

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