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Ranking Factors Influencing Construction and Demolition Waste Generation in Companies of Defined Size Based on Surveys: The Case from the United Arab Emirates

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Abstract

Construction and demolition (C & D) waste management have been the subject of numerous scientific research, yet it is still challenging to put expert knowledge into reality. There is still a gap between theory and practice. The author assumed that if there are problems with the theory's implementation, studying the population of construction workers and their actions can provide a solution. This paper aims to evaluate and rank factors that affect the C & D waste generation in construction companies and how they relate to company size. The research was based on 140 surveys conducted in Sharjah, in the United Arab Emirates (UAE) among construction companies. Companies were divided into 5 groups depending on the number of employees. Factors influencing the C & D waste generation were divided into those occurring in the design phase, construction phase, related to the management of construction products, and work culture. The methodology was divided into two parts: (1) Ranking the factors using central tendency and dispersion, and (2) Examining the relationship between the size of a company and the assessment of the impact of factors on waste generation using the Kruskal Wallis test and post hoc Dunn's test. The analysis of the ranking of all factors shows that factors related to work culture were rated the highest and factors related to product management were rated as having the lowest impact on C & D waste production. The statistically significant difference in assessing the factors' impact on waste generation depending on the size of a company was confirmed for 19 factors out of 30 examined. Based on the results, it can be concluded that the effects of implementing strategies to reduce construction waste are better understood by workers in larger companies than those in smaller ones. It is hypothesized that factors related to finance and education influence employee awareness. To raise awareness, it is necessary, among other things, to support smaller companies in raising awareness of the negative impact of waste on the environment, to have a waste management plan and to train employees in C & D waste management.

Keywords

Construction and demolition waste, Waste management, Waste generation, Construction companies, Surveys, Sharjah, United Arad Emirates

Introduction

As the world moves towards sustainable living, solid waste management should be considered a priority. The linear economy leads us to immerse waste growth [1] and the increased global resource extraction [2]. The alternative to the linear economy is the sustainable management of natural resources embedded in the circular economy introduced by Boulding et al. [3]. The circular economy involves completing the life cycle of products, whereby a product is reused through recovery and recycling rather than being discarded in a landfill when it

has served its purpose [4]. To improve the circular economy in waste management in the architectural engineering industry it is recommended to 'broader research collaboration, harmonizing waste management systems, and analyzing key stakeholders involved in C & D waste management' [5]. Despite a vast number of scientific studies related to C & D waste minimization, there is still a problem in applying professional knowledge to the practice. An unexplored gap remains between the theory and the practice. It was assumed that if there is a problem in applying the theory, the solution to the problem should be sought among the people. The assumptions were also supported by studies [6, 7] that revealed the importance of the awareness of the sustainable C & D waste management benefits among construction workers. Thus, the population of construction workers and their practices to minimize C & D waste should be studied. Applications of waste minimization can differ from company to company. Their application can depend on many aspects, like educational (training, workshops), financial (a budget to educate workers), internal regulations of a company, and management support [8]. These aspects can change depending on how big a company is. The purpose of this study is to rank the factors influencing the generation of C & D waste in construction companies and their relationship to company size.

Literature Review

Numerous publications cover the subject of C & D waste in literature. C & D waste is defined as the primary waste stream generated in modern society, the amount of which is increasing with today's worldwide urbanization [9]. According to a European Union report from 1999, construction waste is a wide range of materials emerging from the complete or partial construction and/or demolition of buildings or roads, the removal of soil, construction activities, and maintenance initiatives [10]. Federal legislation in the UAE broadly defines solid waste including municipal, industrial, agricultural, medicinal, and construction waste, that must be disposed of and recycled in compliance with the law [11]. In general, C & D waste is any product generated during construction, demolition, or renovation activities, that is considered redundant [12, 13].

Construction waste is classed based on the type of material used in a construction product, for example, concrete, bricks, ceramic tiles, ceramics and gypsum-based materials, wood, glass, plastics, asphalt, tar and tarred products, metals, dirt and earth, insulating materials, mixed building waste, and hazardous construction waste [14, 15]. Construction waste can also be classified based on its material features, such as biodegradable, suitable for landfill disposal or incineration, recyclable, and non-recyclable waste [10].

The mass of generated C & D waste is mainly included in the statistics of a specific country. In the UAE, the latest (2021) government statistics show that the amount of waste collected in 2016 was about 35 million tons, with construction and demolition work generating about 66% of the waste collected [16]. One of the latest research projects that were conducted in Brazil (2022), showed that the production rate of construction waste per built area was 0.22 t/m^2 for new construction work and 0.41 t/m^2 for renovation work, with a unit weight of 0.98 t/m^3 and 0.92 t/m^3, respectively [17]. To estimate the amount of C & D waste the most frequently used is the generation rate calculation method based on the general parameters of a project [18, 19] that was implemented with success in Spain as the Alcores model and in the UK as the SMART Waste system [20].

Each phase of a construction activity contains factors that influence C & D waste production. The sources of C & D waste in the life cycle of a building are considered to occur during the design, product management, and construction phase [15, 21-23], and are also related to the work culture [24-28]. As factors affecting the generation of C & D waste are the core of this paper, they have been studied in detail. Table 1 shows selected factors occurring during the design and construction phase of a building, as well as those related to construction product management and work culture.

The management of the C & D waste should be planned as per sustainable goals written in the 2008/98/EC Directive, based on the latest UN assumptions from the 2030 Agenda. The hierarchy of managing waste is based on the popular 3R rule: reduction, re-consumption, and recycling. Firstly, the waste should be reduced by minimizing the causes that generate it. Secondly, products should be reused, and sent to recycling to support the production of new construction products [9, 29, 30]. The benefits of implementing the 4Rs principle in C & D waste management (reduce, reuse, recycle, and recover) have also been confirmed by significant financial profits, as demonstrated by a study in Abu Dhabi (UAE) [31].

Materials and Methods

A proprietary methodology was developed to analyze and evaluate the factors that generate construction waste to solve the problem presented. The methodology consists of 7 stages:

Stage I: Conducting the literature review and establishing the research scope.

Stage II: Designing a survey.

Stage III: Calculating the size of the research sample taking into account the company structure.

Stage IV: Conducting surveys using the personal interview method and creating an Excel database.

Stage V: Developing statistical analysis methodology and defining statistical methods to analyze selected research areas.

Stage VI: Analyzing obtained research results: statistical analysis of survey data.

Stage VII: Conclusions.

Survey questions were developed based on the literature review. The questionnaire was mainly based on research conducted by Bossink et al. [21] in the Netherlands [24], in Australia [22], in Singapore [26], and in the UAE. The survey questions addressed the construction and material solutions utilized in building construction in the UAE. Questions regarding factors affecting the C & D waste generation were rated by respondents by using the Likert scale from 1 to 5, where:

Table 1: Selected factors occurring during the design and construction phase of a building, as well as those related to construction product management and work culture.

#	Factors affecting the generation of C&D waste	Results of poor C&D waste management
During the design phase		
1	Changes to design after construction commencement	- the demolition and re-erection of the altered parts of the building
2	Lack of knowledge and attention paid to typical sizes of used products	- increased trimming of wrong-fitted sizes
3	Lack of designers' experience in construction	- errors or changes in the design
4	Mistakes in project documents	- subsequent changes and alterations to the building
5	Incomplete project documents at commencing construction	- errors in the erection of the building and, consequently, the re-erection of the building
6	Density of detailing and information in drawings	- errors and subsequent amendments to the project
7	Deficiency of information in drawings	- errors and subsequent amendments to the project
8	Lack of knowledge of substitute products	- use of poorly selected construction products
9	Choice of low-quality products	- the destruction of products during construction and the need to use new products
10	Lack of influence of contractors on the contract documentation	- poorly selected construction products
During the construction phase		
11	Mistakes by tradespersons or workers	- errors and subsequent amendments to the project
12	Accidents due to carelessness	- damage to construction products or the building components
13	Usage of improper material, requiring replacement	- the replacement and thus destroying the originally used construction products
14	Unclear quantity of ordered materials due to inadequate planning	- the ordering of too large quantity of a product, which has the effect of destroying the excess products
15	Information on types and sizes of products to be used was provided too late to a contractor	- misapplication of other construction products
16	Use of faulty equipment	- the destruction of construction products
17	Weather conditions	- the destruction of construction products stored on the construction site or the building itself
18	Products broken by subsequent trades	- the destruction of ordered products
During the product management phase		
19	Errors in ordering products (ordering too large or too small quantity of products)	- excess of the product and its destruction
20	Lack of possibility to order small quantities of products	- the storage of excess products resulting in their destruction
21	Purchase of products that do not meet the required technical specifications	- subsequent repair or replacement
22	Damages due to transporting on-site/to-site	- the destruction of ordered products
23	Incorrect site storage	- the destruction of ordered products
24	Materials supplied are unpacked	- the destruction of ordered products
25	Theft or vandalism	- the destruction of ordered products
26	Disposal of packaging	- the destruction of recyclable products
Related to work culture		
27	Lack of environmental and waste management training	- decreased employees' awareness of C&D waste management benefits
28	Lack of management support for waste management	- decreased employees' awareness of C&D waste management benefits
29	Lack of awareness of the negative impact of waste on the environment	- reduced efficiency in construction waste management
30	Lack of a construction waste management plan	- understating both management support and employee self-monitoring of proper construction waste management

1: Means that the factor has minimal impact on C & D waste generation,

2: Factor has a low impact on waste generation,

3: Factor has a medium impact on waste generation,

4: Factor has a large impact on waste generation,

5: Factor has the greatest impact on waste generation.

The population was assumed to include individuals working in construction companies. Based on the survey sample and employee interviews, the type of respondent was determined to be a senior site manager with at least 10 years of professional experience. The research area includes construction companies registered in the Emirate of Sharjah in the UAE. Due to considerable variances in construction law between separate Emirates, the research area was limited to only one administrative area. Discrepancies in the research outcomes were avoided in this manner.

The population was divided into sub-populations according to the number of employees. The population structure was determined using relevant statistical data, i.e., the percentage share of each subpopulation in the general population. A representative sample size was then calculated for each subpopulation.

In order to obtain as accurate data as possible and to quickly clarify any discrepancies in responses, the survey was conducted using direct interview techniques (personal and

telephone interviews) [32].

The methodology for analyzing selected study areas was separated into two parts: (1) The arithmetic mean for each factor was calculated to establish a ranking of factors influencing the production of construction waste in the surveyed companies, (2) The statistics of the Kruskal Wallis test with the post hoc Dunn's test were calculated to investigate the dependence of these parameters on the size of the company [33].

Methodology for determining the ranking of factors

To determine the ranking of factors the following was done:

The factors affecting the generation of C & D waste were divided into 4 groups: (1) factors occurring in the design phase, (2) in the construction phase, (3) in the product management phase, and (4) related to work culture.

Within each group of factors, a measure of central tendency and dispersion was examined using the arithmetic mean (M), median (Me), standard deviation (SD), minimum, maximum, and skewness (Sk.). Within each group, the factors were ranked from the highest to the lowest mean value.

An analysis of the results obtained was carried out and conclusions were drawn. The influence of factors on waste generation was evaluated as follows:

Minimum, when the mean value is between (0-1),

Small, when the mean value is in the range (1.01-2),

Medium, when the mean value is in the range (2.01-3),

Large, when the mean value is in the range (3.01-4),

Maximum, when the mean value is in the range (4.01-5).

Methodology for examining the dependence of factors' rankings on a company's size

To investigate whether there is a relationship between the ranking of factors and the size of the company, the following was done:

Companies were divided into 5 groups based on the number of employees: (1) 1 - 9 employees, (2) 10 - 49 employees, (3) 50 - 99 employees, (4) 100 - 249 employees, and (5) 250 or more employees.

The respondents' answers concerning the factors affecting the C & D waste generation were classified into 4 groups according to a phase of a project. In each group, the number of responses for each factor was determined on a five-point Likert scale.

The statistics of the Kruskal Wallis test with post hoc Dunn's test were calculated to assess the relationship of the evaluation of the impact of waste generation factors on the size of the company [33, 34]. The p-value determined on the basis of test statistics was compared with the significance level α:

If $p \leq \alpha \Rightarrow$ reject H0 by accepting H1, the result is statistically significant. This means that there is a relationship between the size of the company and the assessment of the impact of the factor on C & D waste generation.

If $p > \alpha \Rightarrow$ there are no reasons to reject H0, the result is statistically insignificant. This means that there is no significant relationship between the size of the company and the assessment of the impact of the factor on C & D waste generation.

The test statistic is calculated according to equation (1):

$$H = \frac{\ddot{u}}{C}\left(\frac{}{N(N+1)} \sum_{j=1}^{k} \left(\frac{\left(\sum_{i=1}^{n_j} R_{ij} \right)^2}{n_j} \right) - 3(N+1) \right)$$

Where:

$N = \sum_{j=1}^{\kappa} n_j \left(number\ of\ companies \right)$, n_j - sample size for (j = 1, 2, ... k), (number of groups of companies to be compared, k = 5), R_{ij} - ranks assigned to the values of the variable, for (i = 1, 2, ..., n_j), (j = 1, 2, ... k), (paired comparison groups of companies), C = 1- (Σ(t^2 - t))/(N^3 - N) - correction for tied ranks (when there are no tied ranks C = 1), (the correction for tied ranks is done when there are ranks of the same value; C is the sum of equal ranks), t - number of cases included in the tied rank (in the sample, the number of cases included in the tied rank ranges from 2 to 5; 2 corresponds to two equal tied ranks; 5 corresponds to the maximum number of equal tied ranks, i.e., groups of companies).

A statistically significant result of the Kruskal Wallis H-test says that at least one group is different from another group. Therefore, additionally post hoc Dunn's test was used. In the study, Dunn's test is applied for those factors for which the p-value for Kruskal Wallis H is <0.05. Dunn's test was used to calculate clear differences between groups of companies in assessing the impact of the factor on C & D waste generation.

Size and structure of the studied population

There are 5 subpopulations among the population of the investigated companies. Each of them consists of companies that employ a specific number of people. Surveys were conducted among 140 general contracting companies. Table 2 shows the population structure.

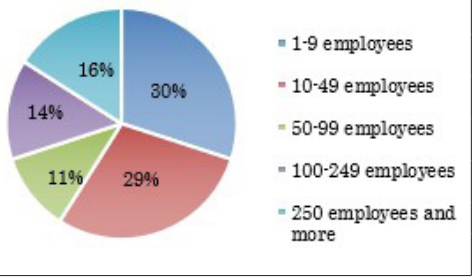
In the surveyed population, 42 companies (30%) have from 1 to 9 employees, 41 companies (29%) have from 10 to 49 employees, 15 companies (11%) have from 50 to 99 employees, 20 companies (14%) have between 100 and 249 employees, and 22 companies (16%) have 250 employees or more. The subpopulation of companies that have the least workers is the largest.

Results

The calculations were made using the computer program SPSS-26. First, descriptive statistics were calculated in each group of factors, then rankings of these factors were created, and then one common ranking was created for all analyzed factors. The findings were then analyzed to assess the impact of factors on C & D waste generation according to company size.

Table 2: The structure of the assessed population.

Number of employees hired in the assessed companies	Number of companies	Percentage share
1 - 9 employees	42	30%
10 - 49 employees	41	29%
50 - 99 employees	15	11%
100 - 249 employees	20	14%
250 employees and more	22	16%
Total	140	100%



Analysis of factors influencing the generation of C & D waste

Table 3 presents an analysis of the factors affecting the generation of C & D waste in 4 selected project stages that respondents identified as most frequently creating minimal, low, medium, large, and greatest amounts of C & D waste.

Based on the obtained results, it can be concluded that in the analyzed case, respondents identified the 'Lack of designers' experience in construction', 'Usage of improper material, requiring replacement', 'Incorrect site storage', and 'Lack of awareness about the negative impact of waste on the environment' as having the most significant impact on C & D waste production.

Determining the ranking of all studied factors

Ranking of factors influencing the generation of C & D waste during the design phase

Descriptive statistics of the factors influencing C & D waste generation during the design phase are provided below in table 4 and ranked according to the mean value from highest to lowest. An analysis of table 4 shows that:

1. None of the factors surveyed were rated as having a minimal, small, or a maximum impact on C & D waste generation.
2. Four factors were rated as having a medium impact on C & D waste generation:
   - 2.1. Lack of influence of contractors on the contract documentation.
   - 2.2. Lack of knowledge of substitute products.
   - 2.3. Deficiency of information in drawings.
   - 2.4. Density of detailing and information in drawings.
3. Six factors were rated as having a large impact on C & D waste generation:
   - 3.1. Choice of low-quality products.
   - 3.2. Changes to design after construction commencement.
   - 3.3. Lack of designers' experience in construction.
   - 3.4. Mistakes in project documents.
   - 3.5. Lack of knowledge and attention paid to typical sizes of used products.
   - 3.6. Incomplete project documents at commencing construction.

The findings demonstrate that respondents highly value knowledge of high-quality building products. It demonstrates that responders are aware of the waste production that erroneous project documents can cause.

Table 3: Analysis of the factors influencing the production of C&D waste in 4 selected project phases.

Generated amount of C&D waste the most frequently assessed by the respondents as:	Factors influencing the generation of C&D waste:			
	In design phase	In construction phase	In product management phase	Related to Work culture
Minimal	'Density of detailing and information in drawings' (29% of companies)	'Use of faulty equipment' (19% of companies)	'Disposal of packaging' (30% of companies)	Lack of management support for waste management' (13% of companies)
Low	'Deficiency of information in drawings' (24% of companies)	'Weather conditions' (24% of companies)	'Theft or vandalism' (52% of companies)	'Lack of environmental and waste management training' (24% of companies)
Medium	'Lack of knowledge and attention paid to typical sizes of used products' (53% of companies)	'Unclear quantity of ordered materials due to inadequate planning' (49% of companies)	'Lack of possibility to order small quantities of products' (46% of companies)	'Lack of environmental and waste management training' (20% of companies)
Large	'Changes to design after construction commencement' (52% of companies)	'Mistakes by trades persons or workers' (42% of companies)	'Disposal of packaging' (29% of companies)	'Lack of management support for waste management' (50% of companies)
Greatest	'Lack of designers' experience in construction' (32% of companies)	'Usage of improper material, requiring replacement' (16% of companies)	'Incorrect site storage' (15% of companies)	'Lack of awareness about the negative impact of waste on the environment' (41% of companies)

Table 4: Descriptive statistics of the factors influencing C & D waste generation were ranked by the mean from highest to lowest during the design phase.

#	Factors influencing C & D waste generation during the design phase	Mean (M)	Standard deviation (SD)	Median (Me)	Minimum	Maximum	Skewness (Sk)
1	Choice of low-quality products	3,60	1,00	4,00	1,00	5,00	-0,87
2	Changes to design after construction commencement	3,56	0,84	4,00	1,00	5,00	-0,55
3	Lack of designers' experience in construction	3,56	1,20	3,00	1,00	5,00	-0,11
4	Mistakes in project documents	3,43	0,91	4,00	1,00	5,00	-0,44
5	Lack of knowledge and attention paid to typical sizes of used products	3,34	0,88	3,00	2,00	5,00	0,51
6	Incomplete project documents at commencing construction	3,04	1,06	3,00	1,00	5,00	0,04
7	Lack of influence of contractors on the contract documentation	2,83	1,10	3,00	1,00	5,00	-0,38
8	Lack of knowledge of substitute products	2,82	0,89	3,00	1,00	5,00	-0,26
9	Deficiency of information in drawings	2,67	1,08	3,00	1,00	5,00	0,30
10	Density of detailing and information in drawings	2,41	1,10	3,00	1,00	5,00	0,14

Ranking of factors influencing the generation of C & D waste during the construction phase

Table 5 provides descriptive statistics of the factors influencing C & D waste generation during the construction phase and ranks them according to the mean value from highest to lowest. An analysis of table 5 shows that:

1. None of the factors surveyed was rated as having a minimal, small, or a maximum impact on C & D waste generation.
2. Three factors were rated as having a medium impact on C & D waste generation:
   - 2.1. Unclear quantity of ordered materials due to inadequate planning.
   - 2.2. Weather conditions.
   - 2.3. Use of faulty equipment.
3. Five factors were rated as having a large impact on C & D waste generation:
   - 3.1. Mistakes by tradespersons or workers.
   - 3.2. Use of inappropriate material, requiring replacement.
   - 3.3. Products broken by subsequent trades.
   - 3.4. Information on types and sizes of products to be used was provided too late to the contractor.
   - 3.5. Accidents due to carelessness.

According to the findings, respondents prioritize timely and proper project management, including the work of tradespeople, to reduce waste production.

Ranking of factors influencing the generation of C and D waste due to poor product management

Table 6 provides descriptive statistics of the factors influencing the generation of C & D waste due to poor product management and ranks them according to the mean value from highest to lowest. An analysis of table 6 shows that:

1. None of the factors studied were rated as having a minimal, small, large, or a maximum impact on C & D waste generation.
2. All factors in the product management phase were rated as having a medium impact on C & D waste generation.

Table 5: Descriptive statistics of the factors influencing C & D waste generation were ranked by the mean from highest to lowest during the construction phase.

#	Factors influencing C & D waste generation during the construction phase	Mean (M)	Standard deviation (SD)	Median (Me)	Minimum	Maximum	Skewness (Sk)
1	Mistakes by tradespersons or workers	3,50	0,96	4,00	1,00	5,00	-0,27
2	Usage of improper material, requiring replacement	3,35	1,03	3,00	1,00	5,00	-0,03
3	Products broken by subsequent trades	3,28	0,92	3,00	1,00	5,00	0,09
4	Information on types and sizes of products to be used was provided too late to a contractor	3,21	1,02	3,00	1,00	5,00	-0,32
5	Accidents due to carelessness	3,09	1,09	3,00	1,00	5,00	-0,08
6	Unclear quantity of ordered materials due to inadequate planning	2,99	1,08	3,00	1,00	5,00	0,01
7	Weather conditions	2,99	1,02	3,00	1,00	5,00	-0,13
8	Use of faulty equipment	2,90	1,18	3,00	1,00	5,00	-0,23

Table 6: Descriptive statistics of the factors influencing the generation of C&D waste due to poor product management ranked by the mean value from highest to lowest.

#	Factors influencing C & D waste generation during the management phase	Mean (M)	Standard deviation (SD)	Median (Me)	Minimum	Maximum	Skewness (Sk)
1	Incorrect site storage	2,94	1,25	3,00	1,00	5,00	0,19
2	Lack of possibility to order small quantities of products	2,89	1,08	3,00	1,00	5,00	0,01
3	Disposal of packaging	2,86	1,46	3,00	1,00	5,00	-0,07
4	Materials supplied are unpacked	2,76	1,20	3,00	1,00	5,00	0,34
5	Errors in ordering products	2,73	1,04	3,00	1,00	5,00	-0,02
6	Damages due to transporting on-site/ to-site	2,71	1,05	3,00	1,00	5,00	0,56
7	Purchase of products that do not meet the required technical specifications	2,69	1,39	2,00	1,00	5,00	0,52
8	Theft or vandalism	2,40	1,16	2,00	1,00	5,00	0,99

The findings reveal that respondents do not place a high value on the product management process, as all factors were considered to have a medium impact on waste production. Among the above-mentioned factors, the factor 'Incorrect site storage' was assessed as having the greatest impact on waste production.

Ranking of factors influencing the generation of C & D waste related to work culture

Table 7 provides descriptive statistics of the factors influencing C & D waste generation related to work culture and ranks them according to the mean value from highest to lowest. An analysis of table 7 shows that:

1. None of the factors studied was rated as having a minimal, small, medium, or a large impact on C & D waste generation.
2. All work culture factors were rated as having a high impact on C & D waste generation.

The findings indicate that respondents place the highest value on having a waste management plan and being aware of the negative impact of waste on the environment to reduce waste generation.

Ranking of all factors influencing the generation of C and D waste

Figure 1 shows the ranking of all the factors affecting the generation of C & D waste, ranked by the mean value from maximum to minimum.

The analysis of the graph presented in figure 1 shows that the respondents mostly rated factors associated with the work culture as generating the most C & D waste among all the rated factors. This was followed by highly rated factors in the design phase and factors in the construction phase. Factors related to product management were rated lowest. Respondents gave the highest rating to the factor 'Lack of a construction waste management plan', and the lowest was to 'Theft or vandalism'. These results demonstrate the importance of continuous development in construction management for respondents, who place a high value on raising awareness of the harmful effects of C & D waste on the environment.

Differences in the assessment of the impact of factors on C & D waste generation among companies of different sizes

To test whether there were significant differences in the factors' assessment of the impact on C & D waste generation according to the size of the company, the statistics of the Kruskal Wallis test with Dunn's post hoc test were calculated. Table 8 shows the calculated statistics where statistically significant results are shown in bold. Dunn's test was performed for each statistically significant result to test for differences in factor influence scores between companies. The differences obtained are described as e.g., d > a, which means that for a given factor, a company with 100 - 249 employees (d) has higher assessment scores than a company with 1 - 9 employees (a).

Discussion

Based on the calculations conducted in table 8 it is possible to determine, with high probability, whether there were significant differences in the assessment of the factor's impact on the generation of C & D waste depending on the size of a company. The results of the calculations did not confirm a

Table 7: Descriptive statistics of the factors influencing C & D waste generation related to work culture ranked by the mean value from highest to lowest.

#	Factors influencing C & D waste generation related to work culture	Mean (M)	Standard deviation (SD)	Median (Me)	Minimum	Maximum	Skewness (Sk)
1	Lack of a construction waste management plan	3,84	1,27	4,00	1,00	5,00	-0,95
2	Lack of awareness of the negative impact of waste on the environment	3,81	1,26	4,00	1,00	5,00	-0,80
3	Lack of management support for waste management	3,59	1,11	4,00	1,00	5,00	-1,02
4	Lack of environmental and waste management training	3,30	1,31	3,00	1,00	5,00	-0,14

statistically significant difference in the factor's impact assessment, depending on the size of the company, for the 11 factors examined (refer to table 8 - the factors mentioned above are not highlighted). For the above-mentioned factors, assessments of their impact on C & D waste generation did not differ significantly between the individual groups of companies analyzed.

Of the 30 factors studied, 19 found a dependence of the factor's impact assessment on waste generation on the company's size. The statistically significant results are highlighted and shown in bold in table 8. Figure 2 presents charts showing trends of statistically significant results in each project phase.

Impact on C & D waste generation according to the company size in each phase of a project

In the design phase, 40% of the results are statistically significant. This demonstrates that there are considerable discrepancies in estimating the impact of 40% of factors on C & D waste production amongst companies of various sizes. The 'Lack of knowledge and attention paid to typical sizes of used products' was the factor that differentiated companies the most. Companies with 100 to 249 employees rated that factor as having a greater impact on C & D waste generation than smaller companies with 1 to 9, and 10 to 29 employees. This could relate to training, i.e., the financial assistance that employees in larger companies benefit from. On the other hand, the foregoing findings demonstrate that there is an approximate impact assessment of 60% of factors on C & D waste production among the companies analyzed. That is the evidence that employees in the examined population of companies are aware of the importance of C & D waste sources in the design phase, as proven by related study [18].

According to numerous research studies, the majority of construction waste generation happens during the design stage and subsequent construction [15-17]. Current study analysis findings support this. During the construction phase, 57% of the results are statistically significant, whereas 43% are not. Employee assessments differ greatly or are approximately in nearly half of the studied organizations. It demonstrates that 43% of surveyed employees believe that factors occurring during the construction stage have a significant impact on C & D waste output (Table 5 and figure 1), and their opinion does not differ significantly across company sizes (Table 8 non-statistically significant results are not highlighted). However, 57% of them hold significantly opposing views. Small

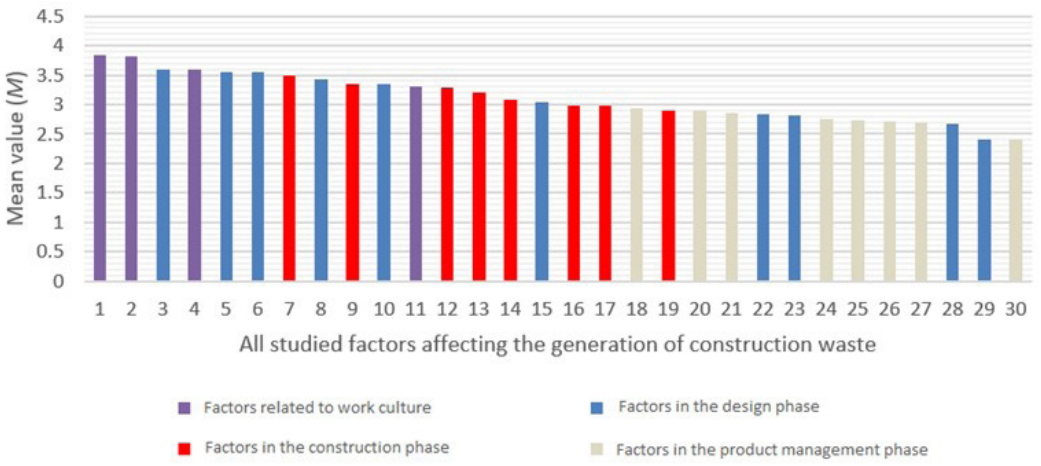


Figure 1: The ranking of all C&D waste generators ranked by the mean value from highest to lowest.

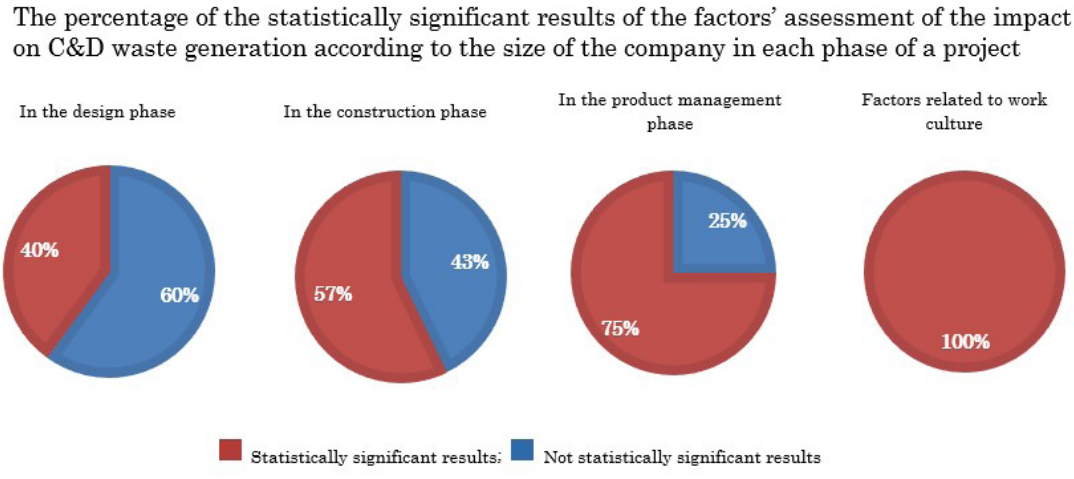


Figure 2: The percentage of the statistically significant results of the factors' assessment of the Impact on C&D waste generation according to the company size in each phase of a project.

Table 8: The Kruskal-Wallis test statistics with post hoc Dunn's test of differences between companies of different sizes for the assessed factors.

#	Factor influencing the generation of C&D waste	Surveyed companies divided as per the number of employees															H Kruskal-Wallis	p	Dunn's test
		a 1 - 9 (n = 42)			b 10 - 49 (n = 41)			c 50 - 99 (n = 15)			d 100 - 249 (n = 20)			e 250 and more (n = 22)					
		M	ME	SD	M	ME	SD	M	ME	SD	M	ME	SD	M	ME	SD			
1	Changes to design after construction commencement	3,36	4,00	0,82	3,78	4,00	0,65	3,60	4,00	0,63	3,65	4,00	0,81	3,41	3,50	1,22	6,222	0,183	
2	Lack of knowledge and attention paid to typical sizes of used products	3,14	3,00	0,52	3,05	3,00	0,89	3,47	3,00	0,83	4,10	4,00	0,97	3,45	3,50	0,96	19,600	0,001	d>a; d>b
3	Lack of designers' experience in construction	3,43	3,00	1,42	3,39	3,00	1,05	4,00	4,00	1,07	3,90	4,00	0,97	3,50	4,00	1,22	5,502	0,240	
4	Mistakes in project documents	3,43	4,00	0,91	3,27	3,00	0,87	3,27	3,00	0,70	3,85	4,00	0,81	3,45	3,50	1,14	6,696	0,153	
5	Incomplete project documents at commencing construction	2,93	3,00	0,64	2,76	3,00	1,09	3,20	3,00	0,68	3,70	4,00	1,34	3,05	3,00	1,36	10,351	0,035	a>b; b<c; b<d
6	Density of detailing and information in drawings	2,19	2,00	1,31	2,27	3,00	1,03	2,60	3,00	0,51	2,95	3,00	1,05	2,50	3,00	1,01	9,377	0,052	
7	Deficiency of information in drawings	2,21	2,00	0,75	2,61	3,00	0,89	3,53	4,00	0,74	3,35	3,00	1,39	2,45	2,50	1,22	26,175	<0,01	a<c; a<d; b<c; c>e
8	Lack of knowledge of substitute products	2,60	3,00	0,80	2,85	3,00	0,82	3,40	4,00	0,99	2,75	3,00	0,91	2,86	3,00	0,99	8,595	0,072	
9	Choice of low-quality products	3,64	4,00	0,69	3,29	4,00	1,15	4,07	5,00	1,39	3,65	4,00	0,67	3,73	4,00	1,08	8,483	0,075	
10	Lack of influence of contractors on the contract documentation	3,00	3,00	1,10	2,37	3,00	1,20	3,33	4,00	0,90	2,75	3,00	0,91	3,09	3,00	0,92	12,528	0,014	b<c
11	Mistakes by tradespersons or workers	3,88	4,00	1,04	3,29	3,00	0,84	3,67	4,00	0,82	3,50	3,00	0,89	3,05	3,00	0,95	16,354	0,003	a>b; a>e
12	Accidents due to carelessness	3,12	3,00	0,55	2,68	3,00	1,06	3,00	3,00	1,07	3,60	3,50	1,39	3,41	3,50	1,37	8,698	0,069	
13	Products broken by subsequent trades	3,67	3,00	0,87	3,12	3,00	0,78	2,93	3,00	0,59	3,50	4,00	1,00	2,86	3,00	1,08	14,437	0,006	a>e
14	Usage of improper material, requiring replacement	3,33	3,00	0,48	3,20	3,00	1,19	3,47	4,00	0,99	3,80	4,00	1,20	3,18	3,00	1,30	7,143	0,129	
15	Unclear quantity of ordered materials due to inadequate planning	2,83	3,00	0,62	2,76	3,00	1,16	3,00	3,00	0,76	3,75	3,50	0,85	3,05	3,00	1,62	13,335	0,010	c>a; c>b
16	Information on types and sizes of products to be used was provided too late to a contractor	3,17	3,00	0,82	3,61	4,00	0,92	3,13	3,00	1,06	3,10	3,00	1,17	2,73	3,00	1,16	8,833	0,065	
17	Use of faulty equipment	3,17	3,00	0,62	2,41	3,00	1,30	3,60	3,00	1,50	3,20	3,00	1,01	2,55	3,00	1,26	13,043	0,011	b<a, b<c, b<d, c>e
18	Weather conditions	3,26	3,00	0,80	2,66	3,00	1,06	3,13	3,00	0,83	3,80	4,00	1,01	2,23	2,00	0,75	30,879	<0,01	a>e; b<d; d>e
19	Damages due to transporting on-site/to-site	2,81	3,00	0,86	2,78	3,00	1,01	2,67	3,00	0,90	3,10	2,00	1,45	2,09	2,00	0,97	10,447	0,034	d<b
20	Incorrect site storage	2,69	2,50	1,00	2,90	3,00	1,45	2,87	3,00	1,06	3,55	3,00	1,36	2,95	3,00	1,25	5,638	0,228	
21	Materials supplied are unpacked	2,83	3,00	0,82	2,17	2,00	1,07	3,53	4,00	1,64	3,85	4,00	1,09	2,23	2,00	0,75	33,959	<0,01	d>a; d>b; d>c; d>e
22	Theft or vandalism	1,98	2,00	0,47	2,29	2,00	1,05	3,13	3,00	1,51	3,25	3,00	1,48	2,14	2,00	1,17	17,862	0,001	a<d
23	Disposal of packaging	2,55	3,00	1,29	2,88	2,00	1,54	2,93	4,00	1,67	3,70	4,00	1,34	2,64	2,50	1,36	9,947	0,041	a<d

24	Errors in ordering products	2,74	3,00	0,54	2,63	3,00	1,22	3,13	3,00	0,99	3,05	3,00	0,89	2,32	2,00	1,39	8,895	0,064	
25	Lack of possibility to order small quantities of products	3,02	3,00	0,35	2,95	3,00	1,41	3,47	4,00	0,83	2,85	3,00	1,35	2,18	2,00	0,91	19,274	0,001	d<a; d<c
26	Purchase of products that do not meet the required specifications	2,40	2,00	0,59	2,44	2,00	1,48	3,40	4,00	1,68	3,85	4,00	1,09	2,18	1,00	1,65	23,416	<0,01	d>a; d>b; d>e
27	Lack of environmental and waste management training	3,17	3,00	1,29	2,85	3,00	1,28	3,40	4,00	1,30	4,35	5,00	0,99	3,36	3,50	1,22	18,475	0,001	d>a; d>b
28	Lack of management support for waste management	3,71	4,00	0,64	3,17	4,00	1,24	4,20	4,00	1,01	3,90	4,00	1,37	3,45	4,00	1,14	16,872	0,002	c>b
29	Lack of awareness of the negative impact of waste on the environment	4,60	5,00	0,66	3,05	3,00	1,43	3,67	3,00	1,18	3,90	4,00	0,97	3,77	4,00	1,27	29,916	<0,01	a>b
30	Lack of a construction waste management plan	4,57	5,00	0,67	3,00	3,00	1,48	4,00	4,00	1,13	4,25	4,00	0,55	3,55	4,00	1,30	30,637	<0,01	a>b; a>e

companies with 1 to 9 employees, for example, rated the factor 'Mistakes by tradespersons or workers' as having a bigger impact on C & D waste generation than companies with 10 to 29, and 250 or more employees. It is considered that this is due to financial and time management issues, which are more important in small businesses [6, 7].

In the product management phase, 75% of the outcomes are statistically significant. A large proportion of the companies polled have considerably divergent views on the impact of these factors on C & D waste production. Companies with 10 to 49 employees, for example, rated the factor 'Damages due to transportation on-site/to-site' as having a bigger impact on C & D waste generation than companies with 100 to 249 employees. Again, it demonstrates that small businesses are looking for ways to save money. However, it should not be regarded as a norm in the assessment of factors throughout the product management phase. Companies with 100 to 249 employees, for example, rated the factor 'Materials supplied are unpacked' as having a bigger impact on C & D waste creation than all other companies. Additional research should be conducted to determine the cause of this phenomenon.

Among work culture-related factors, 100% of the results are statistically significant. A previous study has indicated that factors connected to work culture have a significant impact on C & D waste generation [19-23]. Thus, the disparities in employee evaluations can be deemed concerning. According to the findings in table 3, the majority of respondents rated factors related to work culture as having a high influence on the creation of C & D waste. Table 7 and figure 1 also demonstrated satisfactory evaluation, since employees rated, for example, the factor 'Lack of awareness about the negative impact of waste on the environment' as having the highest impact on C & D waste output. However, the findings in table 8 indicate a disparity in employee opinions across companies of various sizes. The significance of the post hoc Dunn's test is evident here. For example, the aforementioned factor was found to have a greater impact on waste creation in organizations with 100 to 249 employees than in companies with 1 to 9, and 10 to 49 workers. Furthermore, organizations with 50 to 99 employees rated the factor 'Lack of management support for waste management' as having a greater impact on C & D waste production than companies with 10 to 49 employees. The trend is unclear, since the smallest businesses with 1 to 9 employees rated the two last factors (Table 8) as having a greater impact on C & D waste output than businesses with 10 to 49, and 250 or more employees. Thus, additional research should be conducted to determine the causes of these inconsistencies.

Conclusions

The study's objective was to create a ranking of the factors influencing C & D waste production in construction companies and its relationship to the company size. Companies were categorized into the following groups based on the number of employees: 1 to 9, 10 to 49, 50 to 99, 100 to 249, and 250 or more. The rankings of factors influencing C & D waste generation related to the design phase, construction phase, product management phase, and work culture were examined. Both descriptive statistics and factor rankings impact on the generation of C & D waste confirm prior research that revealed the bulk of C & D waste is created during the design and later construction stages. Findings derived from conducted surveys also confirm previous studies that show the critical influence of factors related to work culture on C & D waste generation. In general, the findings in table 3 to table 7, and figure 1 simply confirm previous studies. While the data in table 8 show specific variances in company evaluation based on company size. Two groups of findings can be derived from table 8: Statistically insignificant and statistically significant. The findings in the first group of factors imply that employees from various sizes of companies evaluated the impact of 11 factors on C & D waste production to be approximate. However, in the second group, 19 of the 30 analyzed factors demonstrated a statistically significant relationship between the factor's impact evaluation on waste generation and the company size. Among the findings in this group, employees from larger companies who rated the impact of factors on C & D waste production as greater than employees from smaller companies may be impacted by a lack of training. As a result,

smaller business workers may have less expertise and awareness of C & D waste reduction methods. These findings can also be linked to financial and time constraints, as managers in smaller companies may have less time to attend, organize, and finance training. Prior publications support above mentioned conclusions. Finances can also have a significant impact on the implementation of the C & D waste minimization methods. Companies with smaller budgets, i.e., smaller companies, are looking to save money by preventing C & D waste through, for example, avoiding employee errors or reducing damage to building products. The current investigation revealed these findings in the analyses of factors in the construction and product management phases. Nonetheless, the most novel findings are shown in the examination of factors influencing C & D waste production associated to work culture. The findings in each case are statistically significant. This demonstrates how inconsistent appraisal is among companies of varying sizes. It is possible that the causes of this phenomenon are related to finances, training, internal company regulations, and external legislation.

Recommendations

The investigations in this paper considerably improve the knowledge of reducing C & D waste. It proves that the problem of C & D waste generation is more complex. It is not enough to determine factors that affect C & D waste production, because this knowledge is still insufficient to improve waste reduction. The issue is with construction workers, and the outcomes of this research narrow the issue and bring us closer to resolving it. It is necessary to level awareness among construction workers about the harmful environmental impact of waste. A significant role is played by financial assistance offered by a municipality, as well as affordable training and workshops. Furthermore, investigations on the behavioral factors that affect C & D waste production in companies of all sizes are recommended.

Acknowledgments

Nil

Conflict of Interest

Nil

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