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Construction and Demolition Waste Management in Urban Transformation: A Case Study for Performance Evaluation

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Abstract: Due to the decreasing resources in the world, different recycling applications in different sectors are gaining more importance. Urban transformations initiated especially for earthquake remnants and old buildings provide many advantages for the construction sector. Recycling of valuable materials from the wastes from each demolished construction site is very important in terms of costs. It is also important to analyse the effectiveness of both public and private companies to compare different approaches and illustrate best practices. From this point of view, this research has been carried out on the recycling of construction and demolition wastes in Turkey and the performance of companies dealing with this business. Analytical hierarchy process (AHP) and gray relations analysis (GRA) will be applied for the evaluation phase. The criteria will be analysed through AHP and the connection between companies will be determined with the GRA method. According to the results, potential improvement opportunities will be identified to increase the performance and competitiveness of construction excavation companies. This will also allow the findings to serve as a potential model for other construction companies operating under different contingency factors, as well as presenting the list of criteria that construction companies should pay attention for performance evaluation.

Keywords: Construction, demolition waste management, multi criteria decision making

1. Introduction

Waste management is a method that is developed to optimize dwindling world resources. In this regard, studies were conducted primarily, such as Villalba et al. (2002), more than two decades ago to measure the recyclability of materials. However, with the circular economy concept developed later, these studies started to gain momentum (Huysman et al., 2017). Within this developing process, waste types were divided into domestic, industrial, agricultural, construction and demolition, hazardous, medical, and special waste (Ferronato & Torretta, 2019).

When these wastes are investigated, construction and demolition waste (CDW) is one of an area that affects the environment and should be adequately managed. Urban transformation/renewal is one of the leading causes of construction and demolition waste (Yazdani et al., 2021). In order to build the houses needed by the increasing population, the old buildings must be transformed, and the new buildings must be sustainable in order not to repeat this situation (Yıldız et al., 2020).

In the global world, cities are reshaped by transforming physically, socially, and culturally. As a result, there is fierce competition between cities in many ways. In this race, cities see the urban transformation process as an

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opportunity and aim at transformation and innovation in physical space. With the urban transformation, abandoned rift areas in the city are revitalized, the city is developed healthily and effectively, the city's economy is strengthened, and its quality of life is increased (Hölscher & Frantzeskaki, 2021). Depending on all these, it aims to develop the city in a planned way, have multi-participation and secure investment opportunities, and become an important centre of attraction with the urban transformation studies.

The urban transformation has sustainable goals with economic, social, and environmental dimensions (Huning et al., 2021). Efforts can be made to efficiently use the land, increase job opportunities, attract new investments, and transform traditional trade and industry. It includes protecting local characteristics in social aspects, creating social environments, improving living conditions, building residences and public buildings according to needs and culture, and increasing job opportunities. Environmental objectives reveal approaches such as physical improvement of the built environment, establishing environmental infrastructure, and protecting natural structures and resources. However, appropriate end-of-life activities should be conducted during the urban transformation to follow these sustainable goals. Due to the research area, this study mainly focused on implementations in Turkey. Urban transformation in Turkey first started to prevent squatting. Later, with the construction sector being the backbone of the Turkish economy in the following stages, it was taken under control by the institutions established by the state and the laws enacted (Zavvar Sabegh et al., 2016). In Turkey, municipalities, the central government, the private sector, and citizens carry out urban renewal projects of various types (Gün et al., 2021). Considering the scope and implementation of these projects, urban transformation projects are carried out due to transformation, gentrification, the transformation of central business areas, transformation with prestigious projects, preservation of protected sites and transformation for tourism purposes, transformation initiated by the public and primarily appealing to the middle-income group, natural disasters in rift areas and slum areas (Assi et al., 2020).

Due to the increasing urban transformation in Turkey, it is important to consider wastes caused by construction and demolition activities. Therefore, it is essential to define performance criteria for organizations in the sector to ensure that their activities align with sustainable practices. Furthermore, it is important to analyse the effectiveness of both public and private companies to compare different approaches and to show the best practices. From this point of view, this research is conducted on the recycling of construction and demolition wastes and the performance of companies engaged in this business in Turkey. To do so, this study aims to answer the following research questions:

- Which criteria should be used in the performance evaluations of companies related to construction waste and recycling?
- What is the current performance status of these companies?
- Do private or public companies work more efficiently in recycling construction waste?

To answer all these questions, a systematic structure will be followed. First, all the data obtained by applying to state and private companies will be obtained. Then, criteria set will be created by conducting a literature search and determining the ones that can be useful from these data. The analytical hierarchy process (AHP) and gray relations analysis (GRA) will be implemented for the evaluation phase. The link between criteria and companies will be analysed through AHP, and GRA will further analyse these results.

The structure of this paper is as follows. After the introduction, the part will focus on giving theoretical information related to the CDW sector and performance evaluation. In the third part, the research methodology is explained. The fourth part includes the implementation of the study. After that, implications, discussions, and conclusion parts are presented.

2. Background Information Related to Construction and Demolition Waste Management

Due to increased global urbanization, it is essential to primarily recycle construction and demolition wastes to protect natural resources, prevent waste, reduce the amount of waste stored, and use them as secondary raw materials (Aslam et al., 2020). Furthermore, it is necessary to use proper methods to separate these wastes at their source to obtain good quality recycling material and reduce costs (Kabirifar et al., 2021). Construction and demolition wastes are highly recyclable and reusable in the same sector or different areas (Jin et al., 2017). Therefore, properly managing construction and demolition wastes is important for the environment, where both environmental and economic benefits can be gained. Due to its high impact, recycling should be considered very important in managing construction and demolition wastes.

During the planning of recycling of demolition wastes, usually, the 4R (recycling, reuse, recovery, reduction) principles are strategically implemented (Kabirifar et al., 2020; Purchase et al., 2021). The 4R principle should be applied meticulously in terms of good resources management and sustainable environmental management. To understand recycling well, it is crucial to understand and know these concepts well to know exactly what is meant by 4R in the construction and demolition sector (Lauritzen, 2018). In this manner, recycling refers to conserving resources and reducing the amount of waste discharged for reuse and recovery and is a common term used to reduce the amount of waste (Kumar & Rao, 2017). Reuse is used to define after processing the location and new buildings or renovation and demolition of buildings and the use of the more or less original shape of the material for the original purpose (Reddy et al., 2018).

On the other hand, recovery is obtaining resources from waste (Purchase et al., 2021). For example, materials obtained from wastes and used as secondary raw materials, such as using scrap metals as raw materials, are in this group. Finally, reduction refers to changing the waste state, as is the degree, size reduction, or mitigation actions (Kabirifar et al., 2020). For example, the size or amount of waste is made smaller by obtaining energy in incinerators. The use of non-recyclable wood wastes or hazardous wastes to obtain energy by burning is in this group.

CDW can be defined as waste materials generated during the construction, renewal, restoration, or demolition of buildings. CDW constitutes the majority of urban waste. CDW, which generates 350 million tons per year in the European Union (EU), is the most significant waste (Whittaker et al., 2021). In addition, 30% to 40% of waste in China originates from CDW (Huang et al., 2002), and this rate is 27% in Canada (Yeheyis et al., 2012). The waste and pollution created by such a large amount of waste are environmentally and socially uncomfortable. Recycling these wastes both reduces the number of landfills and provides economic advantages. The most important advantages are the acquisition of recycled raw materials and the job creation of those who will collect, separate, and recycle (Khoshand et al., 2020; Iodice et al., 2021).

In the construction and demolition processes, there are methods to be followed to reduce the occurrence of waste recycling and also to increase recyclability. During these processes, it should be avoided to order excess amounts of materials or materials that are not suitable for the end-of-cycle activities. Furthermore, appropriately storing the materials is also critical. Therefore, it is also essential to ensure the recycling of waste by making a plan in which wastes will be reused and recycled by creating an area where wastes can be separated and stored in the construction or demolition area. Moreover, before the contractor firm starts to work in the construction area, the waste recycling process should be planned and specify where and how to use construction and demolition wastes in future projects. If waste is managed correctly in the construction and demolition sector, recyclable material will increase, and environmental and economic gains will be achieved (Wu et al., 2019).

CDWs contain many types of recyclable materials. Although these recyclable materials have many sub-items, they can be evaluated in four main groups. These main groups can be classified as aggregate, metal, wood, and plastic. In the study conducted by (Stenis & Hogland, 2014), the wastes generated were divided into twenty-five groups, and a material analysis of these wastes was made. These twenty-five items: Steel scrap, Wood, Copper scrap, Porcelain and tile, Galvanized steel plate, Stainless steel, PVC, Aluminium scrap, Zink scrap, Galvanized steel, PE/PP, Asphalt, Chipboard, Plaster, Plywood, Concrete, Gravel or stone, Sand gravel, Garden waste, Gypsum Glass wool, Rock wool, Water-based paint, Solvent-based paint, Lightweight concrete blocks. Furthermore, Yeheyis et al. (2012) divided the recyclable CDWs in Canada into thirteen groups: asbestos, aluminium, brick and block, cardboard, concrete, gypsum board, steel, insulation, glass, ceramic, plastic, paint, and wood.

As seen clearly, there are very limited studies to integrate the concepts of CDW Management. Unfortunately, none of these studies have focused on the criteria and problems companies face. So, this study focuses on identifying criteria and analysing the cause and effect relationship between each criterion based on CDW Management Performance. Therefore, next section provides criteria are determined and categorized as quantitative and qualitative factors.

3. Criteria for Evaluating Construction and Demolition Waste Management Performance

Developing and changing technologies, and social and environmental factors that emerged due to demographic changes have increased attention to the construction and demolition sector. Depending on the development of this sector, the number and variety of studies on this subject have increased. Huang et al. (2002) conducted a study showing the importance of machinery in separating construction wastes and showed how technological developments affect the construction industry. Li et al. (2020) examined the environmental impact of demolition waste and addressed environmental problems in the study. While Garbarino and Blengini (2013) research mentioned the economics of recycling in the construction and demolition sectors, in the latter study, Bao and Lu (2020) explained the productive circular developments created by CDWs in developing country's economies. More analysis-based studies on this subject have obtained important information for the academic and business environment. For instance, Yuan (2013) made a SWOT analysis of successful construction waste management in his study.

Furthermore, Lu et al. (2021) conducted a study on the density of construction waste with the help of big data. Wang et al. (2019) showed the relationship of the construction industry with society with the study. Economic feasibility studies were also carried out along with these social, environmental, and scientific research. The financial and economic assessment of CDW recycling examined the Hanoi region of Vietnam; a similar study by Zhao et al. (2010) revealed the economic feasibility of recycling CDW in the Chongqing region of China.

Although there are studies that examine factors of social, environmental, economic, and technological factors in the CDW sector, as mentioned briefly, none of these studies evaluated companies currently engaged in CDW work against each other by using specific criteria for CDW. Therefore, from this point of view, the below criteria that include both quantitative and qualitative factors are suggested with the support of the previous studies to evaluate the performances of companies currently engaged in CDW work will be evaluated.

***Stored amount**:* Although the amount stored may seem like a good amount at first glance, the number that should be specified here is the amount of waste that is idle, not used in 6R activities, and is complete garbage. Since these wastes cannot be recycled for the economy and create environmental pollution, the smaller the amount, the better (Coelho & De Brito, 2013; Gomes et al., 2011; Listes & Dekker, 2005).

Distance to the customer*:* Distance to the customer is a negative factor because it increases logistics costs and makes transportation difficult. In this research, the research was also included due to the transportation and traffic difficulties caused because the excavation areas are far from the construction areas in the city (Moslemi et al., 2017).

Sales (weight): Sales figures come to the forefront with the benefits it brings back to the economy, the environment, and recycling, rather than the income benefit. Waste recycled or sold as filling material creates an economy by reprocessing or using it (Park et al., 2017).

Number of Excavation Facility**:** The increase in the number of excavation facilities reduces logistics costs by facilitating transportation and providing economic advantages (Coelho & De Brito, 2013; Guo & Kluse, 2020)

The number of Recycle Facilities (C1)**:** The number of recycling facilities is as significant as the number of excavation areas. Because if construction waste cannot be recycled, it can only be used for reuse as a filling material. Therefore, the number of recycling facilities is also significant in creating benefits (Karagoz et al., 2021; Ahmadi-Javid et al., 2017).

Vehicle Value: One of the criteria is the value of the vehicles. Due to these vehicles, it is ensured that the wastes are transported quickly from the construction area to the excavation area (Guarnieri et al., 2020). Unfortunately, many companies in Turkey outsource this transportation business to third-party companies. The main reason is that the intermediate value is preferred according to the number of vehicles; there is a wide variety of vehicles and their capacities.

Machine Value: The machines used are the main assistants at the point of stacking and recovering excavation loads. With the help of machines, many activities such as stacking, sorting, reprocessing, and shredding are carried out. In parallel with the vehicle values, it was seen that the evaluation of the values of the machines would be more consistent rather than the number of machines, considering the diversity, capacities, sizes, and working speeds of the machines used (Ozturk et al., 2016).

Employee Amount: A large number of employees directly helps in sharing the workload, arranging the working hours better, and increasing the productivity of the employees by reducing the work intensity (Kheybari et al., 2019; Sagnak et al., 2021).

Employee Education Degree*:* The fact that an employee is educated and qualified directly affects working efficiency. For this reason, the education level of the employees is an essential criterion in terms of performance. Therefore, in this study, we count those with a vocational school or a bachelor's degree among the three companies as trained personnel (Özceylan et al., 2016).

In the following section, the research methodology is explained in detail.

4. Research Methodology

Construction waste and recycling are important issues, as explained in the previous sections. As the number of constructions and residences increases, the rate of raw materials required increases accordingly. For this reason, it is important to meet some of the needs from here by recycling construction wastes to protect resources. For this purpose, performance evaluations will be made by comparing the companies engaged in construction and excavation work using the methodology of this study, GRA. First, the weights of the criteria presented in the previous sections will be calculated with the help of the AHP by collecting expert opinions. Then, by using the GRA model, these companies will evaluate and rank by integrating AHP results. At the end of this study, the weaknesses and strengths of public and private companies in the CDW business will be revealed and evaluated. The flow of this study is presented in Figure 1.

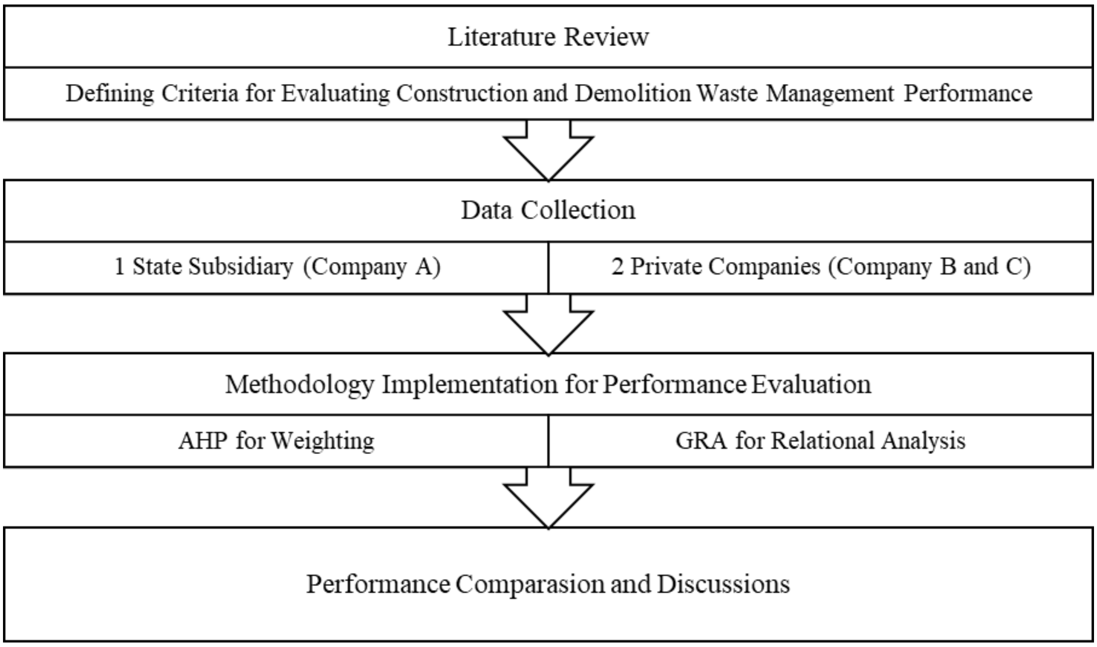

Fig. 1 - Flow of the study

In the following sub-sections, AHP and GRA analyses are presented, respectively.

4.1 The Analytical Hierarchy Process

The AHP (Saaty, 1977) is a way of addressing measurable and abstract criteria in the decision-making process. It is a MCDM method based on a pairwise comparison of alternatives according to a criterion. In AHP method, experience of decision makers guides the computations and it can deal with both quantitative and qualitative concepts, while ranking the criteria.

AHP consists of three main stages. First, a hierarchical structure is created to solve the problem in AHP. After the hierarchical structure is created, the pairwise comparison matrix showing the relative importance of the criteria and the superiorities are determined and calculated (An et al., 2007). The eigenvector method is used to calculate the relative importance. Then the consistency ratio is determined, and the consistency of the values in the matrix is checked (Garcia-Cascales & Lamata, 2009). If the consistency rate is acceptable, priority is given to alternatives. Thus, the alternative with the highest value is selected.

Step 1: Providing the Hierarchical Structure and Problem Formulation

In AHP method, problems are divided into levels and hierarchical structure represents the model. With modelling, the decision-maker can evaluate all levels in the hierarchy.

Step 2: Creation of matrix and Scale of preference between two elements

The second step of AHP is the pairwise comparison matrix. In this part calculation is made for the relative importance of each criterion, which is conducted by pairwise comparison.

After creating the comparison matrix and giving the numerical values to the criteria with the help of the table in Table 1, what needs to be done is to calculate the relative importance levels between the criteria. First, the binary comparison matrix calculates the relative importance level (Saaty, 1994). Then the consistency analysis begins.

Table 1 - The linguistic scale

Preference weights	Definition
1	Equally preferred
3	Moderately preferred
5	Strongly preferred
7	Very strongly preferred
9	Extremely preferred
2,4,6,8	Intermediates values

Step 3: A consistency analysis

Consistency analysis is applied while calculating the consistency rate of the AHP Method. Equation 1 is applied, and a consistency index is found.

$$CI = \lambda_{max}/(n-1) \quad (1)$$

The consistency ratio is reached by dividing the consistency index by the incidental indicator (Equation 2) shown in Table 2.

$$CR = TI/RI \quad (2)$$

Table 2 - Random consistency index

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

According to Table 2, the CR value must be less than 0.10. If a value greater than 0.10 comes out, all matrices written by the evaluations should be examined. After the arrangements are made, the steps should be repeated. The repetition of the steps continues until the consistency ratio is less than 0.1.

4.2 Grey Relational Analysis (GRA)

The GRA system was developed by Julong (1989), and the foundations of the theory were opened in 1989. The application fields of the Grey System is very wide and applicable for all sector.

Six main steps should be followed to conduct GRA Analysis, which are explained below:

Step 1: Data set preparation and decision matrix creation

Suppose that m refers to of alternatives; and each alternative has n criteria for evaluation, where i indicates the row and j indicates the columns.

$$x_i = \{x_i(j), \ldots, x_i(n)\} \ i = 1, 2, \ldots, m \ and \ j = 1, 2, \ldots, n \quad (3)$$

Alternatively signed as row subscript *i*, evaluation criteria as column index *j*, then construct the first decision matrix. x_i (j), j corresponding to the criterion i is the entity in the data array.

Step 2: Creating the reference series and comparing the matrix

The reference series is used to compare alternatives. The reference series is derived from the normalization matrix from the best indicator of the alternative. Provides the useful indicator x_0 (j) on Equation 4.

$$x_0 = \{x_0(j), \ldots, x_0(n)\} \quad j = 1, 2, \ldots, n \quad (4)$$

Then the reference series are added to the decision matrix and converted to the comparison matrix.

Step 3: Normalization process and creation of the normalization matrix

Since different scales and measurement units are used in the decision problem, we need to convert the data set to a single scale for a healthy comparison. There are three types of normalization processes belonging to the properties of the criteria. Benefit attribute (the more, the better):

If the more significant value positively affects the target, Equation 5 is used to calculate the normalization values, where $x_i(j)$ is transformed into x_i^*, and $\max_j x_i(j)$ is the maximum value of criterion j, and $\min_j x_i(j)$ refers to the minimum value:

$$x_i^* = \frac{x_i(j) - \min_j x_i(j)}{\max_j x_i(j) - \min_j x_i(j)} \quad (5)$$

Cost attribute (the less, the better): If, the lower value positively impacts the target, Equation 6 is used to calculate normalization values.

$$x_i^* = \frac{\max_j x_i(j) - x_i(j)}{\max_j x_i(j) - \min_j x_i(j)} \quad (6)$$

Optimal attribute: If the decision maker determines the optimal values, Equation 7 is used to calculate the normalization values. In optimal attribute the target value is $x_{0b}(j)$ and $\max x_i(j) \geq x_{0b}(j) \geq min\ x_i(j)$

$$x_i^* = \frac{|x_i(j) - x_{0b}(j)|}{\max_j x_i(j) - x_{0b}(j)} \quad (7)$$

Step 4: Creating the absolute values table

The absolute value between x^*_0 and x^*_1 is found by Δ_{0i} (j) and calculate with Equation 8.

$$\Delta = |x_0^*(j) - x_i^*(j)| \;\; i = 1, 2, \ldots, m \; and \; j = 1, 2, \ldots, n \quad (8)$$

Step 5: Calculating the gray correlation coefficient for each alternative

Gray relational coefficient matrix Calculation by Equation 9, 10 and 11:

$$\gamma_{0i}(j) = \frac{\Delta_{min} + \xi\Delta_{max}}{\Delta_{0i}(j) + \xi\Delta_{max}} \quad (9)$$

$$\Delta_{max} = \max_i \max_j \Delta_{0i}(j) \quad (10)$$

$$\Delta_{min} = \min_i \min_j \Delta_{0i}(j) \quad (11)$$

In Equation 9, the parameter ζ indicates the discriminant coefficient and represents the significance of Δmax, where $0 \leq \zeta \leq 1$, and the smaller the ζ, the higher the distinguishability. Most studies in the literature $\zeta = 0.5$ because it offers moderate discriminative effects and good stability.

Step 6: Calculating the grey relational degree Γ_{0i}

The gray relational rating calculation is calculated in different ways of priority weight for criteria. If criteria have equal priority weights, Equation 12 is used to calculate.

$$\Gamma_{0i} = \frac{1}{n}\sum_{j=1}^{n} \gamma_{0i}(j) \quad (12)$$

If criteria have different priority weights w_i, Equation 13 is used to calculate the gray relationship degree.

$$\Gamma_{0i} = \frac{1}{n}\sum_{j=1}^{n} w_i(j)\gamma_{0i}(j) \quad (13)$$

5. Implementation of the Study

In this study, the performances of companies currently engaged in CDW work are evaluated, where the AHP and GRA methods mentioned in the previous chapter are used. The AHP method will be used to determine the criterion weights, and the GRA method will be used to choose among the options.

The research started with the data collection process. The quality, quantity, and accuracy of the data to be obtained are essential for the quality of the research. In Turkey, the municipalities carry out excavation soil construction waste control regulation, determination of excavation areas, and license and licensing procedures. The Ministry of Environment and Forestry with the law published in the Official Journal dated 18.03.2004 and numbered 25406.

Under the Waste Management Department, the construction wastes branch directorate deals with construction wastes in Izmir metropolitan municipality. As a result of the application made to this directorate, an annual report containing the information of three companies was obtained. Among these companies, which we will describe as A, B, and C, A is a state subsidiary, while companies B and C are private organizations. After the data was received, phone and face-to-face interviews were held with the officials of these three companies to confirm the data and obtain new information.

Considering the quantitative and qualitative features, an evaluation criterion set consisting of nine criteria are prepared and presented as stored amount (C1), distance to the customer (C2), sales (weight) (C3), number of excavation facility (C4), number of recycling facility (C5), vehicle value (C6), machine value (C7), employee amount (C8), and employee education degree (C9).

In total, eight experts from the field participated in the study to evaluate the presented criteria. Details of these experts are given in Table 3.

Table 3 - Information related to experts

Expert	Area of Expertise	Sector	Position	Experience	Gender
1	Construction Engineer	Construction	Contractor	9	Male
2	Construction Engineer	Construction	Contractor	16	Male
3	Landscape Architect	Landscape	Architect	4	Female
4	Interior Architecture	Construction	Interior Architecture	12	Male
5	Landscape Architect	Landscape	Freelance Architect	4	Female
6	Builder	Demolition	Foreman	9	Male
7	Construction Engineer	Demolition	Architect	9	Male
8	Landscape Architect	Landscape	Landscape Architect	4	Male

To start with the data collection phase related to companies mentioned in the previous paragraphs, Table 4 is structured where data related to each criterion and company are presented. Furthermore, these criteria are specified as positive or negative, where positive indicates the higher is better, and negative indicates that the lower is, the better.

Table 4 - Data set of the companies & criteria

Company	C1	C2	C3	C4	C5	C6	C7	C8	C9
A	1419969020	29,00	220148410,00	3	2	42695557,88	56729252,78	851	15,21
B	178053000	34,00	155849000,00	1	1	0	3150015,82	30	6,66
C	58326754	70,00	36953250,00	2	1	0	1610000,00	18	11,76
+/-	-	-	+	+	+	+	+	+	+

A matrix is created by taking expert opinions to define the criterion weights. In this part, the experts were asked to rate the importance of the criteria against each other by using the linguistic scales presented in Table 1. Finally, aggregated evaluation matrix is presented in Table 5.

Table 5 - Aggregated evaluation matrix

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1,00	3,00	0,20	3,00	0,33	7,00	0,33	5,00	5,00
C2	0,33	1,00	0,20	1,00	0,20	0,33	0,33	3,00	3,00
C3	5,00	5,00	1,00	3,00	3,00	9,00	5,00	7,00	9,00
C4	0,33	1,00	0,33	1,00	0,33	5,00	1,00	3,00	5,00
C5	3,00	5,00	0,33	3,00	1,00	7,00	3,00	5,00	7,00
C6	0,14	3,00	0,11	0,20	0,14	1,00	0,14	0,33	3,00
C7	3,00	3,00	0,20	1,00	0,33	7,00	1,00	3,00	7,00
C8	0,20	0,33	0,14	0,33	0,20	3,00	0,33	1,00	3,00
C9	0,20	0,33	0,11	0,14	0,14	0,33	0,14	0,33	1,00

Sum	13,21	21,67	2,63	12,68	5,69	39,67	11,29	27,67	43,00

After applying the steps of AHP, the weights of the criteria are derived as in Table 6. Results showed that sales value constitutes the highest value with 0.32 for all criteria. While the number of recycling facilities is in the second place, the machine value and the amount of storage have equal importance at 0.12. Finally, the least important is the education level of the employees with 0.02.

Table 6 - Weights of the criteria

Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
Weights	0,12	0,05	0,32	0,09	0,20	0,04	0,12	0,04	0,02

In the next stage, the information and the weights of the collected data are revealed, and thus, by completing the AHP, the data is made suitable for the GRA model, as shown in Table 7.

Table 7 - GRA model dataset

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
A	1419969020,00	29,00	220148410,00	3,00	2,00	42695557,88	56729252,78	851,00	15,21
B	178053000,00	34,00	155849000,00	1,00	1,00	0,00	3150015,82	30,00	6,66
C	58326754,00	70,00	36953250,00	2,00	1,00	0,00	2167094,50	18,00	11,76
Weights	0,12	0,05	0,32	0,09	0,20	0,04	0,12	0,04	0,02
+/-	-	-	+	+	+	+	+	+	+

After completing the AHP analysis, the GRA method is used for ranking the three companies. Then, the GRA method is applied using the reference series and performing the normalization process. Also, the 'State Value of the coefficient' is determined. After all these stages, the coefficients are obtained with the GRA model. The final table is obtained by multiplying the coefficients found here with the weights obtained from the AHP method. These coefficients and weights are given in the final Table 8.

Table 8 - Final results

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**Sum**	**Rank**
A	0,04	0,05	0,32	0,09	0,20	0,04	0,12	0,04	0,02	0,92	1
B	0,10	0,04	0,19	0,03	0,07	0,01	0,04	0,01	0,01	0,50	2
C	0,12	0,02	0,11	0,05	0,07	0,01	0,04	0,01	0,01	0,43	3

With the method used and the research done, the performance evaluation within three companies emerged. Among these companies, company A, a state subsidiary, got a better score than the other two companies, with 0.92. Company B is in second place with 0.50, while Company C is in the last place with 0.43. Discussions related to results are presented in the next section.

6. Discussion of the Results

After examining all the results, it is revealed that company A, a state-owned company, is ahead in all qualitative parameters compared to private companies. The main reason behind this result is that it is affiliated with the municipality and does not have to make a profit. Furthermore, this company fully has local government support, which is an essential strength. The importance of government support is crucial for the construction sector in terms of regulatory frameworks, grants, and subsidies, as well as it is a significant client of the industry (Bamgbade et al., 2018). When the performance criteria are evaluated according to their importance, in other words, weights, it the revealed that sales have the highest weight. Two main reasons can be stated for this result; firstly, the income obtained from the sale. With the increase in this income, the recycling business will become more attractive and develop and create new business opportunities. Secondly, the amount sold waste is somehow recovered and returned to the economy and the nature. This will provide an environmental advantage as it will help conserve the world's dwindling resources as these sold resources are obtained from the end of life activities. In other words, higher sales of recycled products promote the development of the desire to recycle, which would benefit all stakeholders (Zhai & Lu, 2021).

The number of recycling facilities is the second most crucial criterion, where value-added activities such as separation, shredding, and reprocessing are conducted, and CDWs are efficiently treated. These facilities are also crucial in creating job opportunities for the nearby society, increasing the economic gain by using CDWs for different purposes, and better end of life treatment, reducing the unused CDWs and decreasing the negative environmental impacts.

As a negative criterion, where a higher amount refers to higher waste, the amount of storage criterion is in the third place of the important order. The problem with the amount of storage is that companies do not have a storage space capacity problem, and they can accept all incoming CDWs. They also generate income from the incoming loads whether they sell or recycle them, which results in unused and stored CDWs and consequently has negative impacts on the environment. Therefore, the amount of CDW remaining as waste harms the performance of companies.

The criterion of machine value has the same weight as the amount of storage and shares the third place. This shows the importance of machine utilization in CDW treatment activities. Furthermore, for the applied case, machine value is more important than the criteria related to employees.

The rest of the results can be discussed as follows; the number of excavation sites is vital in terms of increasing accessibility, but the reason why it is not as important as the recycling facility might be that the CDWs coming to these areas can only be sold as filler material and the remaining amount is garbage. However, if the number of excavation sites is low and the location is inaccessible, people may start to find other places for these wastes. For example, in some places in Turkey, it is known that rubble and waste are piled up in various places due to the shortage of excavation places.

As a qualitative criterion, the distance to the customer is important in providing service to a high range of customers. Therefore, facilities far from the city centre are a negative factor due to increased logistics costs, carbon emissions, and low accessibility.

Results showed that the degree of employee education has the lowest weight. This shows that the CDW sector does not require highly educated employees, and it can be said that practical work experience has a better value in this sector. Although this sector can be defined as labour-intensive and requires physical effort during processes, training, and education related to occupational health and safety, waste management can benefit organizations for the long-term well-being of employees. Furthermore, to support needed employees, new programs can be considered in the vocational schools, where the main principles of the CDW sector, waste management practices, and end-of-life activities are taught.

As an important composite performance indicator, when companies are compared according to the amount of accepted construction waste, which is calculated as the sum of the amount stored and the amount sold or recycled and the amount sold; It decomposes 13.42% of Company A's total accepted construction waste, is recycled or sold as fill material, resulting in 86.58% of CDWs remaining unused. On the other hand, Company B ensures that 46.67% of the incoming waste is somehow recovered, and in Company C, this rate is 38.78%. Therefore, the performance related to the amount of accepted construction waste indicates that private companies have a better performance in conducting end-of-life activities and, consequently, have lower environmental impacts and higher economic gains.

As mentioned before, a state-owned company, company A, dominates the other companies for most of the performance criteria, except the stored amount, which results in increased waste. The dramatic difference appears especially in sales, where the weight of company A is greater than the total weight of companies B and C. This result shows company A's economic power and market dominance over private companies. On the other hand, results also showed that the performance of companies B and C, where both are private organizations, are close to each other, and only slight differences have occurred between performance criteria. An example of the only difference is the distance to the customer. Company B dominates company C due to their current locations, i.e., in the city centre versus a town outside the city centre.

In short, when evaluating these three companies, company A has a good performance. However, investments should be made for new applications and improvements in recycling facilities to avoid a high amount of stored CDW, and appropriate methods should be applied to eliminate these wastes and turn them into valuable products. On the other hand, for private organizations, increasing the number of excavation and recycling facilities and investing in machinery are essential to improve their performance. With appropriate initial investments, they can increase their sales and financial power.

7. Conclusion

Due to the decreasing resources in the world, different recycling applications in different sectors are gaining more importance day by day. Urban transformations initiated especially for earthquake ruins and old buildings provide many advantages for the construction sector. Recycling of valuable materials from the wastes from each demolished construction site is very important for costs.

For this purpose, in this study, the performance criteria of the excavation companies operating in the wreckage of a region that experienced an earthquake with a magnitude of 6.0 in 2020, as a result of both earthquake and urban transformation, were investigated. In addition, the effectiveness of both public and private companies is analyzed to compare different approaches and show best practices. For this purpose, firstly, a total of nine performance criteria were determined from the literature specifically for the construction sector. Then, the importance weight of each criterion was calculated with the help of the AHP by referring to the expert opinions, and finally, performance evaluations were made by comparing the companies engaged in construction and excavation work using GRA. Firms were evaluated and ranked by integrating real data and AHP results. At the end of this study, the weaknesses and strengths of public and private companies in the CDW business were revealed. The main reason for this result is that public companies are subordinate to the municipality and do not have to make a profit. In addition, these companies have full local government support, which is a core strength. The importance of government support is crucial for the construction industry in terms of regulatory frameworks, grants and subsidies, proving that the industry is an important customer. The proposed criteria identify potential improvement opportunities to increase the performance and competitiveness of construction excavation companies. This will also allow the findings to serve as a potential model for other construction companies operating under different contingency factors. The results of this study present a roadmap by listing the criteria that construction companies should pay attention to in order to reach a better level of efficiency.

The one of the main limitation of this study is that the construction sector is considered under a single roof and the criteria are general. For future studies, companies in different countries can be compared with more customized criteria in different areas of the construction industry.

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