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AN EVALUATION OF THE TOPICS RELATING TO CONSTRUCTION & DEMOLITION WASTE MANAGEMENT IN GREEN BUILDING CERTIFICATION SYSTEMS*

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Abstract

Activities in the construction sector accelerate resource consumption and solid waste generation, leading to negative environmental impacts. Green building certification systems have been developed since the 1990s to mitigate these effects. These certifications also play an important role in effectively managing construction and demolition (C&D) waste. This study aims to highlight strategies in waste management that can reduce environmental impacts and improve resource efficiency by examining and benchmarking certification systems. Additionally, integrating C&D waste management topics into green building certifications is evaluated. The systematic methodology, including quantitative and qualitative assessments, ensured comprehensive insights into the weight of C&D waste management in certification systems. 31 certification systems were examined, and waste management criteria were assessed, including waste management planning, reuse, recycling, recovery, and landfilling. Based on the findings, the weight of the C&D waste subject in certification systems was compared. Results reveal varying emphasis of certification systems on C&D waste management, with TRUE Zero Waste showing the highest prioritization at 54.32%, while DGNB ranked lowest at 0.92%. Widely adopted certificates such as BREEAM and LEED demonstrated relatively low emphasis on C&D waste topics. The Turkish certification YeS-TR (Building V1-Residential) is placed in the first five certifications considering the weight given to the subject of C&D waste; following this, B.E.S.T.-Residential is coming. This is a crucial step for Tu̇rkiye. The findings highlight the need for robust management strategies to minimize waste, enhance resource efficiency, and reduce environmental footprints, emphasizing the role of certification systems as catalysts for sustainable construction practices.

Keywords: Sustainability in construction, Resource efficiency, Green building certification, Certification systems benchmarking, C&D waste.

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YEŞİL BİNA SERTİFİKASYON SİSTEMLERİNDE YAPISAL ATIKLARIN YÖNETİMİ İLE İLGİLİ KONULARA YÖNELİK BİR DEĞERLENDİRME

Öz

Yapı sektörü etkinlikleri, kaynak tüketimi ve katı atık üretimini artırarak çevre üzerinde olumsuz etkiler yaratmaktadır. Bu etkileri azaltmak amacıyla 1990'lı yıllardan itibaren yeşil bina sertifikasyon sistemleri geliştirilmiştir. Bu sertifikalar, yapısal atıklarının etkin yönetimi açısından da önem taşımaktadır. Bu çalışma, sertifikasyon sistemlerini inceleyip karşılaştırarak, atık yönetiminde çevresel etkileri azaltacak ve kaynak verimliliğini artıracak stratejileri vurgulamayı amaçlamaktadır. Ayrıca, yapısal atık yönetimi konularının yeşil bina sertifikasyonlarına entegrasyonunu değerlendirmektedir. Nicel ve nitel değerlendirmeleri de içeren sistematik metodoloji, sertifikasyon sistemlerinde yapısal atık yönetiminin ağırlığına ilişkin kapsamlı içgörüler sağlamıştır. Araştırma kapsamında 31 sertifikasyon sistemi incelenmiş ve atık yönetimi planlaması, yeniden kullanım, geri dönüşüm, geri kazanım ve düzenli depolama dahil olmak üzere atık yönetimi kriterleri değerlendirilmiştir. Bulgulara dayanarak, sertifikasyon sistemlerinde yapısal atık konusuna verilen ağırlık düzeyleri karşılaştırılmıştır. Sonuçlar, sertifikasyon sistemlerinin yapısal atık yönetimine ilişkin farklı vurgular yaptığını ortaya koymuştur; TRUE Zero Waste %54,32 ile en yüksek önceliği gösterirken, DGNB %0,92 ile en düşük önceliği almıştır. BREEAM ve LEED gibi yaygın olarak benimsenen sertifikalar, yapısal atık yönetimi konularına nispeten düşük bir vurgu göstermiştir. Türkiye'nin sertifikasyon sistemi olan YeS-TR (Bina V1-Konut), yapısal atık konusuna verilen ağırlık göz önüne alındığında ilk beş arasında yer alırken, bunu B.E.S.T.-Konut Sertifikası izlemektedir. Bu durum Türkiye için önemli bir adımdır. Bulgular, atıkları en aza indirmek, kaynak verimliliğini artırmak ve çevresel ayak izlerini azaltmak için sağlam yönetim stratejilerine olan ihtiyacın altını çizmekte, sertifika sistemlerinin sürdürülebilir inşaat uygulamaları için katalizör rolünü vurgulamaktadır.

Anahtar Kelimeler: Sürdürülebilir yapım, Kaynak verimliliği, Yeşil bina sertifikasyonu, Sertifika sistemlerinin karşılaştırılması, Yapısal atık.

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Introduction

Due to the increase in population and rapid urbanization, the increase in production and consumption has been inevitable. This circumstance brings various loads to the environment and economy. Considering the visible consequences of global warming and climate change, sustainability has gained importance in recent years. Within the framework of this concept, which is evaluated under three pillars (social, economic, and environmental), methods such as efficient use of resources, benefiting from renewable energy, water, and energy conservation, and prevention of harmful chemicals should be prioritized to ensure the continuity of the living/non-living environment. Considering that approximately 37% of the carbon emissions that cause the greenhouse effect are directly or indirectly caused by the construction industry (IEA, 2021), the relationship between the architecture discipline and the concept of sustainability gains immense importance.

Considering the global impact of the building industry, sustainable architecture has emerged to maintain the balance between nature and the built environment. Sev (2009) defined this concept as all the activities that use energy, water, materials, and land effectively, prefer renewable energy sources, and consider the comfort and health conditions of the users and the needs of future generations while taking these steps. Green buildings have emerged since the 2000s within the framework of the discipline of

architecture and the concept of sustainability due to adverse conditions such as unconscious consumption of natural resources, environmental pollution, and climate change. It is seen that the widespread use of the green building concept, which is defined as buildings that obtain energy from renewable sources, consume less energy, produce less waste, use environmentally friendly/recyclable building products, and reuse rain and wastewater, has positive effects in solving environmental problems. Therefore, green building certification systems have been developed that are evaluated by civil or governmental organizations within the framework of various criteria such as water, land, energy, waste, materials, transportation, pollution, and innovation.

The construction sector is responsible for the generation of a significant amount of waste from construction and demolition (C&D) activities, which accounts for 40% of the total solid waste in developed countries (Taylor, 2013; Udawatta et al., 2015; Yilmaz & Bakis, 2015). According to the European Commission (2019), only 12% of the materials that are used in buildings in Europe come from recycling, while a significant portion of the materials that are used in construction are disposed of in landfills. By 2027–2028, the global C&D waste recovery market is expected to grow to a value of 149–300 billion US dollars, according to recent analyses (Allied Analytics LLP, 2023; IMARC Group, 2023; Report Ocean, 2021). In the world and Türkiye, the amount of C&D waste generated because of the activities conducted under the name of "urban transformation" has been increasing in recent years, and it is a problem that needs to be managed. Therefore, the issue of C&D waste that has negative effects on the environment and the economy is one of the important topics in green building certification systems.

This study aims to evaluate the role of C&D waste management in global green building certification systems. The study was motivated by the critical need to address the environmental footprint of the construction industry, which contributes significantly to global carbon emissions and resource consumption. There are many studies in the literature that examine green building certification systems from various perspectives. Nguyen and Alten (2011) provided an extensive overview of BREEAM, LEED, and CASBEE, among others, to identify the most suitable scheme based on commercial characteristics. After reviewing 55 assessment methods, Wei et al. (2015) stated that indoor air quality is viewed as an essential factor in all certification tools studied. Yousif et al. (2024) reviewed 52 of the most prominent sustainability green rating systems worldwide from 1990 to 2019, not only for C&D waste but also in every dimension. The comparison shows that all systems have a lot in common. It also highlighted that further studies into green rating systems for developing sustainable construction projects worldwide are needed. Rayhan and Bhuiyan's (2024) study reviewed C&D waste management tools and frameworks but did not address the way the issue was addressed in certification systems specifically or make a comparison between systems. Several studies examine the C&D waste management strategies within certification systems. Can and Taş (2022) emphasized that waste management issues are given importance in LEED v4.1 and BREEAM v6.0 and calculated the scores that can be obtained from material and waste categories. Moody (2021) conducted a research case study based on two different projects, one LEED-certified and the other non-certified, to analyze the different approaches to waste management strategies at Balfour Beatty Construction in San Diego, California. When compared to non-LEED-certified buildings, it was discovered that LEED-certified buildings ultimately have more substantial waste management practices and have a more positive environmental impact. It was emphasized that there is

a lot of information that can be analyzed further about many other certification programs in the world, and it was suggested to look at other certifications in more depth in addition to LEED and evaluate their similarities and differences (Moody, 2021).

In light of these findings, a comprehensive comparison is important to reveal the various green building assessment methods globally in terms of C&D waste management. By systematically analyzing 31 certification systems across six main categories, this study benchmarks their waste management emphasis and highlights improvement areas. The topic is significant because effective management of C&D waste can reduce pollution risks, enhance resource efficiency, and promote sustainable construction practices. This study investigates the integration of C&D waste management into certification systems, identifying priorities for C&D waste management and proposing strategies for a more robust inclusion of waste management practices. The scope of the study encompasses both widely adopted systems like BREEAM and LEED and regionally specific certifications like YeS-TR (Building V1-Residential) and B.E.S.T.-Residential in Türkiye, providing a comprehensive understanding of global and local trends.

As one of the few in the literature that systematically examines the integration of green building certification systems in the context of C&D waste management, this study can fill several important gaps as follows:

- Assessing certification systems comprehensively: The study analyzes 31 different certification systems and evaluates the emphasis each one gives to C&D waste management. This comparative analysis contributes significantly to the literature, which currently lacks information on how these systems approach C&D waste management.
- Making comparisons between developed and developing countries: Comparing systems in developed countries (e.g., LEED, BREEAM) and developing countries (e.g., GRIHA, BERDE) can provide an understanding of the differences between certification systems in different economic and regional contexts in the literature.
- Giving recommendations for certification systems in Türkiye: In the study, evaluating the status of local certification systems such as YeS-TR (Building V1-Residential) and B.E.S.T.-Residential on C&D waste and presenting improvement suggestions can fill the lack of studies in the literature that develop specific suggestions tailored to the context of Türkiye.

A. GREEN BUILDING CERTIFICATION SYSTEMS

Various green building certification systems have been developed by civil or government institutions since the 1990s to reduce/prevent environmental problems. Certification systems are evaluations that examine the environmental impact of buildings in life processes, developed by various industry representatives, academicians, and experts, many of which are voluntary. They have been examining the relations of new and existing buildings with each other and the environment, have been measuring, and have been standardizing how "green" a building is. It consists of various performance thresholds that must be met for the certification of buildings and specific guidelines that will enable project teams to reach these performance thresholds. Certification systems have a variety of rules, such as creating a foundation to anticipate and compare the future performance of buildings, comparing and

refining sample buildings that they reference, and documenting evidence collection for continuous improvement. The systems are designed to suit the climatic conditions, topography, and building industries of the countries where they are developed and to serve the specific requirements of the buildings. Certificates specialize in areas such as buildings with different functions (residential, commercial, industrial, health, sports, education, public, etc.), historical buildings, re-functioning projects, landscape works, etc. Buildings that meet the evaluation criteria obtain points/credits. For the points/credits obtained, they are entitled to receive certificates at different levels specified as "certified, good, very good, excellent" or "bronze, silver, gold, platinum."

The construction industry plays an important role in energy consumption, total natural resource consumption, and emissions. For this reason, various studies are carried out to determine the standards for the buildings. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHREA), the association focusing on the issues of building systems, energy efficiency, indoor air quality, cooling, and sustainability, was founded in the United States in 1894 (ASHREA, 2022). The association, which published the first design standard in 1975, began to be widely used over time. It developed differing rules that defined all building features, such as heating, cooling, ventilation, lighting, and building shell, according to the characteristics of various climatic zones (Baştanoğlu, 2017). The PassivHaus standard, developed in Europe in the 80s, aimed for buildings to consume less energy with the passive design approach (McGraw-Hill, 2008). Building Research Establishment Environmental Assessment Method (BREEAM) was developed in 1990 by Building Research Establishment (BRE), whose foundations were launched in the UK in 1917 (BRE Group, 2022). BREEAM, the first rating system in the world, is the basis for many certification systems, but unlike the ASHRAE and PassivHaus standards, it contains many more evaluation criteria than energy efficiency (Baştanoğlu, 2017). The World Green Building Council (WGBC), which was founded in 1999 in the United States, aims to expand and accelerate the work on sustainable buildings (WGBC, 2022). In Türkiye, the Turkish Green Building Council (ÇEDBİK) was established in 2007 to contribute to the development of the building industry in the light of sustainable principles (ÇEDBİK, 2022). Continuing its activities in the field of green buildings, ÇEDBİK has developed B.E.S.T. (Ecological and Sustainable Design for Buildings)-Residential Certification to be applied in new dwelling projects (B.E.S.T., 2022). Additionally, YeS-TR is Türkiye's national certification within the scope of the Green Certificate Regulation for Buildings and Settlements from the Ministry of Environment, Urbanization, and Climate Change, and published in the Official Gazette in 2022.

Certifications are created for buildings in different functions by examining the climatic conditions of the countries, construction techniques, local materials, and user characteristics; they rate buildings under various headings such as land use, energy efficiency, water efficiency, material and resource use, and waste management. One of the types handled under the waste topic is C&D waste.

B. WASTE IN THE CONSTRUCTION SECTOR AND MANAGEMENT STRATEGIES

Waste caused by construction activities is becoming a major problem worldwide. According to the European Commission (2022), all waste containing a wide range of materials, such as concrete, brick, wood, glass, metal, and plastic, arising from the C&D activities and infrastructure, as well as road planning and maintenance, has been defined as C&D waste. According to Cosgun and Esin (2006), C&D wastes are defined as wastes consisting of all kinds of building products that arise for various reasons throughout the building life cycle. Considering that C&D wastes constitute 13%–29% of the total amount of waste in various countries (Ozturk, 2005), it is important to determine the causes of the formation of these wastes and to measure their amount to take the necessary precautions. Waste is generated in all stages of construction, usage, dismantling, and demolition. Arslan et al. (2012) state that since the usage phase is the longest period of the building, most C&D waste occurs in this phase. In another study, it was found that building materials and components were repaired very frequently in Türkiye, and 74% of these materials were discarded (Esin ve Cosgun, 2005). All components in the building may become waste with the start of dismantling/demolition after the useful life of the building is completed. In addition, large C&D wastes occur because of various natural disasters that have destructive effects, such as earthquakes. Approximately 13 million tons of C&D waste were generated in the Marmara earthquake that occurred in 1999 (Baycan, 2004), and some of these wastes were dumped into the sea, left in empty areas, and/or used as filling material (Arslan et al., 2012). C&D wastes, which are generally a common problem in all countries, have become one of the important problems that have attracted attention in Türkiye in recent years. With detailed waste management plans in many countries, recycling rates of C&D wastes can reach high levels. In Türkiye, there are problems in C&D waste management due to reasons such as insufficient data on the amount of waste (Aksel & Cetiner, 2020), insufficient level of sanctions (Salgin, 2019), and inadequacies in the evaluation of the waste generated. The issue of C&D waste in Türkiye will continue to be a growing problem since unplanned/random demolitions are mostly preferred by managers, building owners, and users instead of techniques such as dismantling and waste management plans that can reduce the formation of C&D waste and the lack of supervision by institutions.

Considering the importance of the problem, it is thought that it should be managed consciously to prevent/reduce C&D waste generation. The zero-waste approach, which has become widespread in recent years, is the concept of waste management, which is defined as prevention, separation, reuse, and recycling of wastes at the source by examining the causes of waste formation, efficient use of natural resources, and reduction of consumption. Within the scope of this concept, the 5R principle stands out principally in the circular economy literature (Reike et al., 2018). The 5R principle is defined as rethink (recreating ideas and processes related to the use of a product and thinking once more), reduce (reducing unconscious consumption), reuse (preferring reusable products), repair (repairing and reusing recoverable products), and recycle (referring products that are suitable for recycling) (Tserng et al., 2021). Later, a more comprehensive approach known as the 10R principle (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover) was developed (Zorpas, 2020).

Demirbas (2011) defined waste management as the collection, transportation, temporary storage, processing, recycling, disposal, or monitoring of waste materials. For healthy waste management, a waste hierarchy should be followed as prevention, preparing for reuse, recycling, recovery, and disposal specified by the Waste Framework Directive (2008/98/EC).

Any construction, renovation, or demolition project needs to be well planned and managed to provide environmental and health benefits and carbon emissions savings as well as financial benefits. A waste management plan should include the steps of dismantling/demolition, who will perform it, the list of materials to be collected, the area to collect waste, the method, and follow-up of the waste, reuse, or final process. This plan should also include the management and safety of hazardous/non-hazardous waste, as well as the limitation of environmental impacts such as leakage and dust. A healthy separation of C&D wastes at source is an important step in the effectiveness of recycling activities, such as the quality of recycled materials. The implementing audits will help monitor a site-specific waste management plan, increase material and labor productivity, reduce waste, and maximize the results achieved (European Commission, 2016).

It is known that many countries are looking for different solutions with the development of technology to cope with the increasing amount of C&D waste. In this direction, all kinds of work done/to be done to prevent, reduce, or manage C&D waste gain importance. If C&D waste is properly managed, the risk of pollution will be reduced, and a valuable source of income can be provided for countries. The issue of C&D waste has an important role in green building certification systems that have emerged to produce environmentally friendly buildings to support the solution of the C&D waste problem. In this context, it is important to examine the issue of C&D waste in certification systems and to determine the current situation.

C. RESEARCH METHODOLOGY

This study employs a systematic approach to analyze the importance and weight of C&D waste management topics in green building certifications. The methodology consists of four steps, as seen in Figure 1.

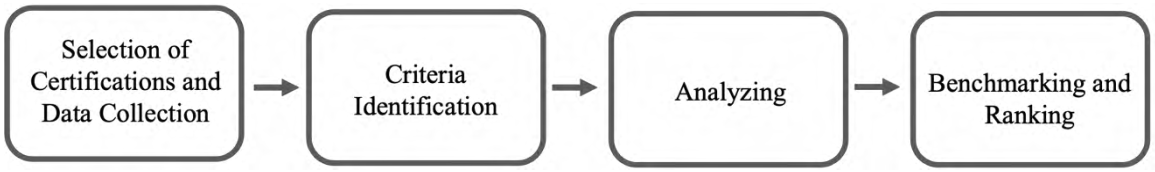

Figure 1. Methodology of the research

Selection of Certifications and Data Collection: A total of 31 internationally recognized, accessible, widely used in the world, and ones that have detailed criteria related to C&D waste management were chosen (Figure 2). "New buildings / new constructions" versions of these certifications were focused. Certification systems that do not contain the subject of C&D waste, which adequate information cannot be accessed, which cannot be obtained due to language differences, and which do

not give concrete documents are excluded from the scope of this study. Data was derived from their latest versions of official certification manuals and guidelines.

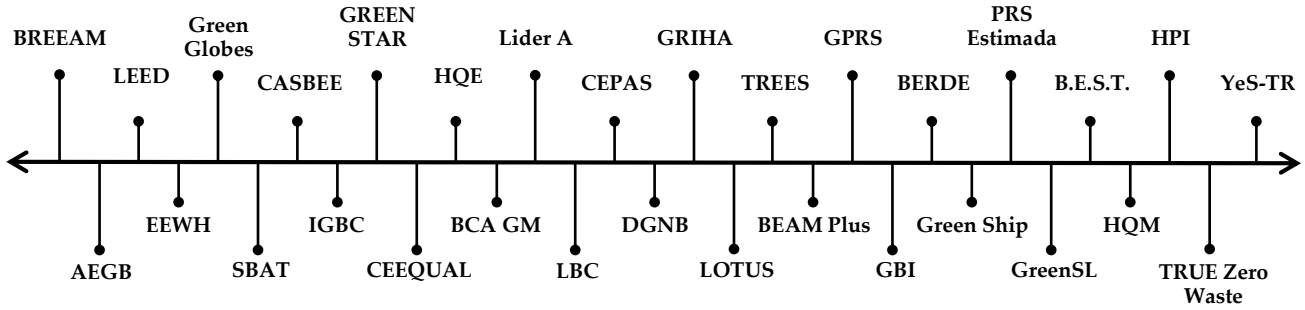

Figure 2. Certification systems examined within the scope of the study (certificates are ordered by their first release date)

Criteria Identification: The analysis focused on examining how C&D waste management is addressed in the "new construction" versions of these certification systems. As a result, it was seen that the criteria evaluating C&D wastes were gathered under the following headings:

- (1) Development of a management plan for C&D wastes,
- (2) Reusing top/vegetative soil, excavation soil, building and building products,
- (3) Recycling, (4) recovery, and (5) landfilling of the building products.
- (6) "Other contents" that will support the effective management of C&D wastes but that are out of these classifications.

Analyzing: Quantitative and qualitative assessments were done. The credits/points allocated for C&D waste management in each certification system were quantified. A comparison was conducted to identify variations in emphasis, approaches, and methodologies for handling C&D waste management issues. It was examined whether the issue of waste was addressed under a special heading. Special attention was given to unique features or innovative approaches within certain systems.

Benchmarking and Ranking: The maximum score/credit that can be obtained from each certification system was determined. Subsequently, the maximum score or number of credits that can be obtained from the "C&D waste management" was determined. Then, these scores were proportioned as a percentage. Certification systems were ranked based on their emphasis on C&D waste management, considering the proportion of credits/points dedicated to this topic relative to the total available credits/points. The systems with the highest contributions to waste-related credits were highlighted. Based on these findings, suggestions are provided for the certification systems being used/developed in Türkiye.

D. C&D WASTE IN GREEN BUILDING CERTIFICATION SYSTEMS

Wastes arising from the construction industry are considered an important topic in certification systems. This part of the study will examine how the issue of C&D waste is handled in the selected 31 certification systems, and the credit/point values that can be obtained are explained.

In **BREEAM** (Building Research Establishment Environmental Assessment Method) - New Construction, C&D wastes are examined under the title of "Waste." Six of the 150 credits can be earned in total from the C&D waste topic. Three credits can be earned from the reuse, recycling, recovery, and landfill of building products, and three credits from other contents that evaluate C&D wastes (BREEAM, 2016).

In **AEGB** (Austin Energy Green Building) - Commercial Rating, C&D wastes are examined under the title of "Materials & Resources." 10 of the 100 points can be earned on C&D waste. Three points can be earned from the reuse of the building and seven points can be earned from the reuse, recycling, recovery, and landfill of building products (AEGB, 2016).

In **LEED** (Leadership in Energy and Environmental Design) - Design and Construction - New Construction, C&D wastes are examined under the title of "Materials and Resources." 12 points can be earned on C&D wastes, where a maximum of 110 points can be obtained, including two points from the reuse of top/vegetative soil, five points from the reuse of the building, five points from the reuse, recycling, recovery, and landfill of building products (LEED, 2019).

In **EEWH** (Ecology, Energy Saving, Waste Reduction and Health) rating system, C&D wastes are examined under the title of "Waste Reduction." From the rating system, where a maximum of 100 points can be obtained, a total of nine points can be earned from C&D wastes within the scope of other contents (EEWH, 2018).

In **Green Globes** - New Construction, C&D wastes are examined under the title of "Materials." A total of 42 points can be earned from C&D wastes, where a maximum of 1000 points can be obtained, including three points from the development of a waste management plan, 22 points from the reuse of the building, four points from the reuse, recycling, recovery, and landfill of building products, and 13 points from the other contents (Green Globes, 2019).

In **SBAT** (Sustainable Building Assessment Tool) - Residential, C&D wastes are examined under the title of "Environment." A total of 0.3 credits can be earned from C&D wastes, where a maximum of 5 credits can be obtained, including 0.2 credits from the reuse of the building, and 0.1 credit from the reuse, recycling, recovery, and landfill of building products (SBAT, 2017).

In **CASBEE** (Comprehensive Assessment System for Built Environment Efficiency) - New Construction, C&D wastes are examined under the title of "Load on Local Infrastructure." A total of 26 points can be earned from C&D wastes, where a maximum of 100 points can be obtained, including two points from the reuse of top/vegetative soil, five points from the reuse of the building, 15 points from the reuse, recycling, recovery, and landfill of building products, and four points from the other contents (CASBEE, 2014).

In **IGBC** (Indian Green Building Council) rating system - New Construction, C&D wastes are examined under the title of "Building Materials and Resources." A total of seven points can be earned from C&D wastes, where a maximum of 100 points can be obtained, including two points from the reuse

of the building and five points from the reuse, recycling, recovery, and landfill of building products (IGBC, 2016).

In **GREEN STAR** – Design & As Built - New Construction or Major Refurbishments, C&D wastes are examined under the title of "Management" and "Materials." A total of 12 points can be earned from C&D wastes, where a maximum of 110 points can be obtained, including one point from the development of a waste management plan, four points from the reuse of the building, six points from the reuse, recycling, recovery, and landfill of building products, and one point from the other contents (GREEN STAR, 2019).

In **CEEQUAL** (Civil Engineering Environmental Quality Assessment and Award Scheme) - Version 6 International Projects, C&D wastes are examined under the title of "Resources." A total of 232 credits can be earned from the C&D waste topic, where a maximum of 5000 credits can be obtained, including 27 credits from the development of a waste management plan, eight credits from the reuse of top/vegetative soil, 43 credits from the reuse of excavation soil, 62 credits from the reuse, recycling, recovery, and landfill of building products, and 92 credits from other contents (CEEQUAL, 2019).

In **HQE** (Association pour la Haute Qualité Environnementale) - Environmental Performance of Non-Residential Building Under Construction, C&D wastes are examined under the title of "Worksite." A total of 23 points can be earned from C&D wastes, where a maximum of 483 points can be obtained, including three points from the development of a waste management plan, two points from the reuse of excavation soil, 14 points from the reuse, recycling, recovery, and landfill of building products, and four points from other contents (HQE, 2016).

In **BCA** (Building and Construction Authority) Green Mark Scheme - Non-Residential Buildings, C&D wastes are examined under the title of "Resource Stewardship." A total of two points can be earned from C&D wastes, where a maximum of 140 points can be obtained, including one point from the development of a waste management plan, and one point from the reuse, recycling, recovery, and landfill of building products (BCA Green Mark Scheme, 2015).

In **Lider A** Version 2.0, C&D wastes are examined under the title of "Environmental Loadings." Instead of a credit or scoring system, the evaluation is made with percentage weights. In total, the weight of C&D waste management issues, which are evaluated within the scope of reuse, recycling, recovery, and landfill of building products and other contents, is 3% (Lider A, 2011).

In **LBC** (Living Building Challenge) 4.0, all 20 sub-criteria in the seven different titles are stated to be mandatory for new productions, and there is no scoring system. In this direction, the evaluation will be made on the number of criteria. C&D wastes are examined under the headings of development of a waste management plan and reuse, recycling, recovery, and landfilling of building products (LBC, 2019).

In **CEPAS** (Comprehensive Environmental Performance Assessment Scheme) 2006 Edition evaluates buildings in four different stages: pre-design, design, construction, and operation. C&D wastes are examined under the title of "Resource Use" and "Loading." A total of 29 credits can be earned from C&D waste, where a maximum of 100 credits can be obtained, including seven credits from the creation

of a management plan, three credits from the reuse of the building, 19 credits from the reuse, recycling, recovery landfill of building products (CEPAS, 2006).

In **DGNB** (Deutsche Gesellschaft für Nachhaltiges Bauen) - New Construction, C&D wastes are examined under the title of "Process Quality." From the certification system, where a maximum of 3800 points can be obtained, a total of 35 points can be earned on C&D wastes within the scope of other contents (DGNB, 2020).

In **GRIHA** (Green Rating for Integrated Habitat Assessment) - V2019, C&D wastes are examined under the title of "Construction Management." A total of seven points can be earned from C&D waste, where a maximum of 105 points can be obtained, including one point from the generation of a management plan, one point from the reuse of top/vegetative soil, and five points from the reuse, recycling, recovery, and landfill of building products (GRIHA, 2019).

In **LOTUS** - New Construction, C&D wastes are examined under the title of "Materials & Resources." A total of five points can be earned from C&D wastes, where a maximum of 110 points can be obtained, including one point from the reuse of top/vegetative soil and four points from the reuse, recycling, recovery, and landfill of building products (LOTUS, 2019).

In **TREES** (Thai's Rating of Energy and Environmental Sustainability) – New Construction and Major Renovation, C&D wastes are examined under the title of "Materials and Resources." A total of 10 points can be earned from C&D wastes, where a maximum of 85 points can be obtained, including two points from the reuse of the excavation soil, two points from the reuse of the building, six points from the reuse, recycling, recovery, and landfill of building products (TREES, 2017).

In **BEAM Plus** (Building Environmental Assessment Method) - New Buildings, C&D wastes are examined under the title of "Integrated Design and Construction Management." A total of 13 credits can be earned from C&D wastes, where a maximum of 211 credits can be obtained, including one credit from the reuse of top/vegetative soil, three credits from the reuse of the building, and nine credits from the reuse, recycling, recovery, and landfill of building products (BEAM Plus, 2019).

In **GPRS** (Green Pyramid Rating System), C&D wastes are examined under the title of "Management." A total of 12 credits can be earned from C&D waste, where a maximum of 173 credits can be obtained, including one credit from the development of a waste management plan, seven credits from the reuse, recycling, recovery, and landfill of building products, and four credits from the other contents (GPRS, 2011).

In **GBI** (Green Building Index) - Non-Residential New Construction, C&D wastes are examined under the title of "Materials & Resources." A total of six points can be earned from C&D wastes, where a maximum of 100 points can be obtained, including one point from the reuse of top/vegetative soil and five points from the reuse, recycling, recovery, and landfill of building products (GBI, 2009).

In **BERDE** (Building for Ecologically Responsive Design Excellence) - New Construction, C&D wastes are examined under the title of "Waste Management." A total of 20 points can be earned from

C&D wastes, where a maximum of 100 points can be obtained, including 12 points from the development of a waste management plan, and eight points from the other contents (BERDE, 2018).

In **GreenShip** - New Building, C&D wastes are examined under the title of "Building Environmental Management." A total of nine points can be earned from C&D wastes, where a maximum of 101 points can be obtained, including one point from the development of a waste management plan, two points from the reuse of the building, three points from the reuse, recycling, recovery, and landfill of building products, and three points from the other contents (GreenShip, 2012).

In **Pearl Rating System for Estimada** – Design & Construction, C&D wastes are examined under the title of "Stewarding Materials." A total of two points can be earned from C&D wastes, where a maximum of 20 points can be obtained, including one point from the development of a waste management plan, and one point from the reuse, recycling, recovery, and landfill of building products (PRS-Estimada, 2016).

In **GreenSL** (Green Sri Lanka) - Built Environment, C&D wastes are examined under the title of "Material, Resources & Waste Management." A total of eight points can be earned from C&D wastes, where a maximum of 100 points can be obtained, including two points from the reuse of the building, and six points from the reuse, recycling, recovery, and landfill of building products (GreenSL, 2018).

In **B.E.S.T.** (in Turkish: Binalarda Ekolojik ve Sürdürülebilir Tasarım) - Residential, C&D wastes are examined under the title of "Integrated Green Project Management." A total of 13 points can be earned from C&D wastes, where a maximum of 110 points can be obtained, including three points from the development of a waste management plan, one point from the reuse of top/vegetative soil, three points from the reuse of excavation soil, three points from the reuse of the building, three points from the reuse, recycling, recovery, and landfill of building products (B.E.S.T., 2019).

In **HQM** (Home Quality Mark) - England, Scotland & Wales, C&D wastes are examined under the title of "Construction Impacts." A total of 16 credits can be earned from C&D wastes, where a maximum of 500 credits can be obtained, seven credits from the reuse, recycling, recovery, and landfill of building products, and nine credits from the other contents (HQM, 2018).

In **HPI** (Home Performance Index) - Version 2.0, C&D wastes are examined under the title of "Environment." A total of eight points can be earned from C&D wastes, where a maximum of 224 points can be obtained, within the scope of the development of a waste management plan (HPI, 2019).

In **TRUE** (Total Resource Use and Efficiency) Zero Waste 2017 is just for the evaluation of waste. A total of 44 points can be earned from C&D wastes, where a maximum of 81 points can be obtained, including 11 points from the reuse, recycling, recovery, and landfill of building products and 33 points from other contents (TRUE Zero Waste, 2017).

In **YeS-TR** (National Green Certification System, in Turkish: Ulusal Yeşil Sertifika Sistemi) – Building V1 - Residential, C&D wastes are examined under the title of "Integrated Building Design, Construction, and Management". A total of 12,2 credits can be earned from C&D wastes, where a maximum of 100 credits can be obtained, including 0,6 credits from the development of a waste

management plan, 10,4 credits from reuse, recycling, recovery of building products, and 1,2 credits from other contents (Official Gazette, 2022).

It was seen that seven of the certification systems examined within the scope of the study include a special title and evaluation criteria under this title related to C&D wastes. In other systems, the subject is discussed under different headings (Table 1):

- Development of a Waste Management Plan: Supported in 23 systems, this criterion emphasizes structured planning as a critical step for effective waste management. A well-defined waste management plan includes specific guidelines for minimizing waste at the source, efficient separation, and tracking waste disposal. The integration of digital tools and technologies could enhance monitoring and compliance with these plans.

- Preservation of Top/Vegetative Soil: Supported in 15 systems, this practice aligns with sustainability goals by maintaining soil integrity for reuse in landscaping or ecological restoration. Systems encouraging this approach contribute to reducing soil degradation and preserving biodiversity, particularly in urban development projects.

- Reuse of Excavation Soil: Supported in 10 systems, this criterion addresses resource efficiency by promoting the repurposing of soil within or outside the project site. This approach also minimizes the environmental impact of soil disposal.

- Reusing Existing Buildings: Found in 14 systems, this practice promotes circular economy principles by encouraging the adaptive reuse of structural elements. It reduces the demand for new construction materials and decreases demolition waste, aligning with climate action goals.

- Reusing Building Products: Supported in 28 systems, this criterion highlights the importance of identifying and reusing components like doors, windows, and fixtures. This strategy is crucial for reducing resource extraction and waste generation in the construction sector.

- Recycling of Building Products: Universally supported across all certification systems, recycling ensures that waste materials like concrete, metals, and plastics are processed and reintroduced into the production cycle. This is a foundational practice for achieving zero-waste goals.

- Recovery of Building Products: Found in 24 systems, this process extracts valuable materials from waste streams, contributing to energy recovery and resource conservation. It is a key mechanism for transforming waste into economic opportunities.

- Landfilling and Separation for Disposal: Supported in 23 systems, this criterion ensures that non-recyclable waste is disposed of responsibly, minimizing environmental risks and further enhancing sustainability.

- Evaluating Waste in Various Ways Based on Certification Dynamics: Found in 15 systems, this practice involves adapting waste management strategies to the specific requirements of the certification system. Tailoring approaches based on regional and project-specific needs increase their effectiveness.

Table 1. Examination of C&D Wastes in Green Building Certification Systems and the Weight of the Topic

Name of the Certification Systems	Level of Consideration of C&D Wastes		Development of a Management Plan	Reuse				Recycling of Building Product	Recovery of Building Product	Landfilling of Building Product	Other Contents about C&D	Weight of C&D Waste Topic in Certificates		
	Custom Title	Sub-Title		Topsoil	Excavation Soil	Building	Building Product					Credit	Point	Percentage
BREEAM												6/150	-	3,99%
AEGB												-	10/100	10%
LEED												-	12/110	10,9%
EEWH												-	9/100	9%
Green Globes												-	42/1000	4,2%
SBAT												0,3/5	-	6%
CASBEE												-	26/100	26%
IGBC												-	7/100	7%
GREEN STAR												-	12/110	10,9%
CEEQUAL												232/5000	-	4,64%
HQE												-	23/483	4,76%
BCA GM												-	2/140	1,42%
Lider A												-	-	3%
LBC												-	2/20	10%
CEPAS												29/100	-	29%
DGNB												-	35/3800	0,92%
GRIHA												-	7/105	6,66%
LOTUS												-	5/110	4,54%
TREES												-	10/85	11,76%
BEAM Plus												13/211	-	6,16%
GPRS												12/173	-	6,93%
GBI												-	6/100	6%
BERDE												-	20/100	20%
GreenShip												-	9/101	8,91%
PRS-Estimada												-	2/20	10%
GreenSL												-	8/100	8%
B.E.S.T.												-	13/110	11,81%
HQM												16/500	-	3,2%
HPI												-	8/224	3,57%
TRUE ZW												-	44/81	54,32%
YeS-TR												12,2/100	-	12,2%

Discussion and Conclusion

Many reasons, such as increased construction industry activities, unaware consumption of resources, and not preferring green building products, harm the natural/built environment. It is important to examine the C&D waste, which is one of the evaluation criteria in certification systems, in this context to produce effective solutions. Proper management of C&D waste can reduce the risk of pollution and make significant contributions to the ecological and economic values of countries. Therefore, certification systems have been reviewed regarding C&D waste management issues. The weight of the C&D waste issue was calculated by dividing the credits/points that can be earned from the criteria targeting C&D wastes with the highest possible credits/points (Table 1). Based on these rates, the certification systems are listed from the system that attaches the most importance to the issue to the system that gives the least importance to the subject (Figure 3).

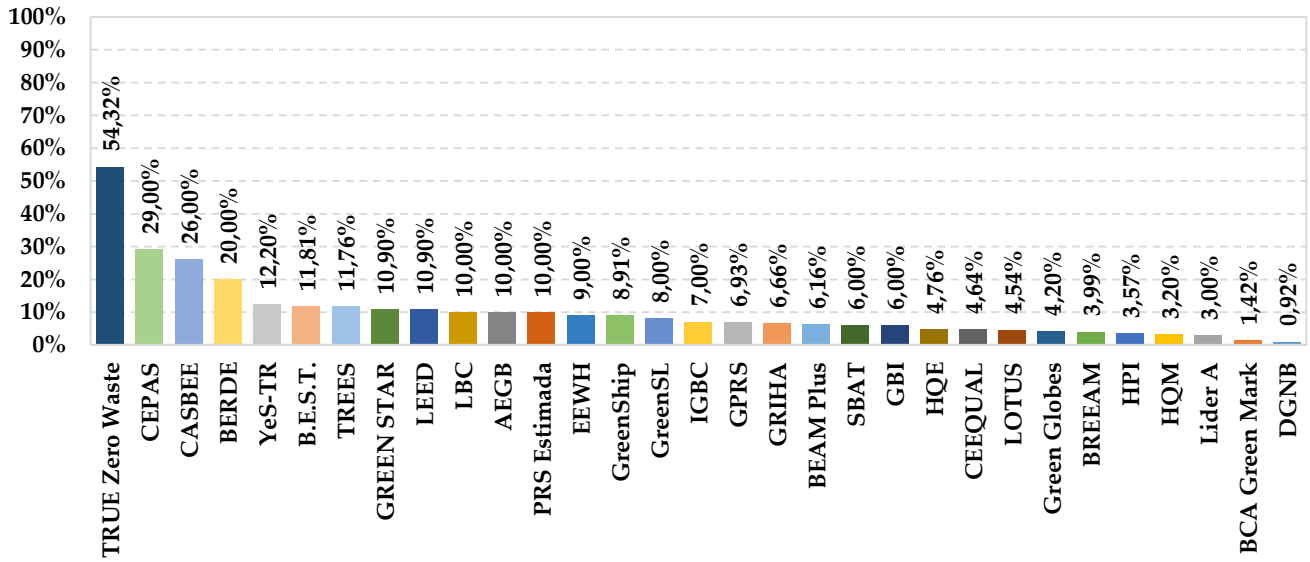

Figure 3. The weight of C&D waste subject in certification systems

In line with the criteria targeting C&D wastes, the TRUE Zero Waste certificate system developed in the USA has the highest content with a rate of 54.32%, while the DGNB certificate system developed in Germany has the lowest content with 0.92%. Since the TRUE Zero Waste certification system is waste-oriented, it has been found consistent to have this rate. However, it was found surprising that the DGNB certification system has the lowest rate despite its widespread use in Germany, which is one of the EU countries that gives importance to C&D waste subject and where many studies have been carried out. CEPAS certification system, one of the first five certification systems according to the weight of C&D waste subject, is used in a densely populated and developed region such as Hong Kong. It is assessed comprehensively as it deals with all stages of the buildings, pre-design, design, construction, and operation. Since the CASBEE certification system developed in Japan examines the environmental loads of the building in detail under a separate title and the BERDE certification system used in the Philippines evaluates the buildings during the design and construction phases, it is thought that they stand out in terms of C&D waste management. It has been observed that certification systems such as BREEAM,

LEED, and GREEN STAR, which have been developed as pioneers in the world and have been widely used for many years, are at the bottom of the weight ranking created within the scope of the study. Although the BREEAM and LEED certification systems contain criteria that comprehensively address C&D wastes, it was remarkable that the weight of the issue was at low levels. While existing systems provide valuable frameworks for managing C&D waste, the improvements listed below can significantly increase their effectiveness:

- Standardizing Practices: Comparability can be achieved by creating consistent standards for evaluating C&D waste across systems.

- Incentivizing Innovation: Additional credits may be offered for projects that use cutting-edge waste management technologies or achieve outstanding recycling rates.

- Integrating Education: Training programs can be organized to raise construction teams' awareness of waste management principles and their application, and additional credits can be earned from these programs.

- Strengthening Monitoring Mechanisms: Robust monitoring systems can be developed to monitor compliance with waste management criteria and ensure accountability.

Regarding Türkiye's perspective, YeS-TR (Building V1-Residential) being among the top five certificates, followed by B.E.S.T.-Residential, is an important development. C&D waste management issues are assessed based on these criteria in YeS-TR (Building V1-Residential) certification: establishing a waste management plan that includes the identification of the types and quantities of waste generated during the construction phase, its accumulation at the construction site, and its recycling; promoting the use of products and materials with minimized environmental impact throughout their life cycle; having documents proving that the wood products used are produced environmentally friendly; using local building materials/products; preferring materials/products that can be reused after being dismantled from existing structures or having recycled content; the project that has flexible design potential; planning the end-of-life process of building materials; planning for the collection and reuse of maintenance/repair and demolition wastes separately. C&D waste within the scope of the B.E.S.T.-Residential certification is assessed based on criteria such as determining waste types, amounts, and disposal methods like reuse and recycling during the construction process and preparing an implementation plan; reusing and/or recycling at least 45% of construction waste by weight and volume; and regularly completing and monitoring the table that tracks monthly waste management progress.

Although YeS-TR (Building V1-Residential) and B.E.S.T.-Residential stand out in terms of their weight given to C&D waste, several inadequacies were identified in their content compared to other certification systems examined in this study. Regarding YeS-TR (Building V1-Residential), these deficiencies include a low utilization rate (5%) of reused, recycled building materials/products in the design; lack of any criterion for the evaluation of vegetative and excavation soil; lack of a mandatory criterion under the requirements for issues addressing wastes; lack of adequate guidance on the disposal of C&D wastes. Regarding B.E.S.T-Residential, the deficiencies include the failure to separately define C&D wastes arising from activities such as maintenance, repair, and demolition at each stage of

construction and usage; the lack of planning and measurement to anticipate the types and quantities of waste generated during construction and demolition stages; low thresholds for reuse, recycling, and recovery rates of C&D wastes within the certification system; the determination of limited waste types while excluding those potentially harmful to the environment and human health; and the failure to specify waste disposal methods.

To align with global best practices, this study suggests incorporating the following strategies for the certification systems being used/developed in Türkiye:

- Bringing principles like 5Rs, 10Rs, etc., to the forefront to prevent waste, increasing the minimum requirements that align with international best practices regarding reuse and recycling percentages for construction materials,

- Emphasizing lifecycle-based evaluation to address long-term sustainability and enhancing its guidelines to include detailed life cycle analysis of construction materials,

- Encouraging research and innovation to expand the range of sustainable construction materials available in Türkiye.

- Defining the types and amounts of waste that may occur throughout the entire building life cycle and evaluating these processes separately,

- Informing and training the responsible people about C&D waste management and disposal methods before starting the project,

- Considering user preferences to prevent the wastes that may arise because of maintenance/repair during the operation process of the building, and accordingly adopting flexible design principles,

- Establishment of a repurchase policy for the surplus quantities of building materials purchased from suppliers,

- Gaining additional points/credits in case of cooperation with building material suppliers who have a zero-waste policy.

- Strengthening collaboration with international bodies to integrate innovative waste management technologies into national projects.

The evaluations and recommendations made within the scope of the study will support the effective management of C&D wastes, which are known for their adverse impact on the living/non-living environment and human health and comfort. It is foreseen that the targets for the effective management of C&D wastes will be achieved faster by encouragement, support, and dissemination of the understanding of environmentally friendly/green building production. It is also thought that this study will present a different and supportive perspective on C&D waste management issues in green building certification systems developed/under development in Türkiye. The criteria of YeS-TR (Building V1-Residential) and B.E.S.T.-Residential align with the targets outlined in Türkiye's Zero Waste Project and Climate Change Mitigation Strategy and Action Plan 2024-2030, which aims to reduce greenhouse gas

emissions and enhance resource efficiency. By integrating these enhancements, Türkiye's certification system could not only align with global standards but also set a precedent for other nations with similar developmental needs. These developments not only support Türkiye's compliance with international environmental agreements but also demonstrate a proactive approach to sustainable urban development.

Ethics Committee Permission

This article is not part of a working group that requires ethical committee approval.

Contribution Rate Statement

The authors contributed equally to the article.

Conflict of Interest

There is no financial conflict of interest with any institution, organization, or person related to this article.

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