

Towards Zero Waste in Construction: A Case Study Using Green Building Certification Systems

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ABSTRACT

In many countries of the world like Turkey there are extensive civil engineering constructions in the forms of buildings, skyscrapers, dams, bridges, canals, culverts, pipes and roads. Each one of these activities lead to wastages that need to be dealt with ecosystem friendly coupled with economic, social and environmental sustainability purposes. Construction materials from the resources through their usages and demolition need special attention for end-product as minimum as wastage generation after reuse possibilities. The linear process of successive resources, usages and landfill end planning is the simplest alternative, which has been applied so far in any country or society, especially, by local governments and companies. Although, between usage and the landfill are interstate reuse benefits, but they are marginal, because the landfills bury large amounts of reuse benefits. Since almost ten years, circular waste treatment programs came into view with extensive consideration, which prior to landfill extracts demolition materials as much as possible for reuse with the aim of zero waste (ZW). The application sources and possibilities of this trend is exposed for Turkish construction circles with the commercialization of more demolished materials for extra economic return. Thus, this study can be useful to policy and decision makers in developing the ZW guidelines in construction sector by using Site Waste Management Plans (SWMP)s.

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Introduction

Solid waste management is one of the most important urban services, yet it is complex and expensive, accounting for approximately 20 % of municipal budgets in low-income countries and 10% of municipal budgets in high-income countries [1]. Sources of solid waste generation are residential, commercial, institutional in addition to construction and demolition waste (CDW), municipal solid, industrial, agricultural and treatment plant wastes [2]. CDW is the heaviest among waste streams which accounts approximately for 25% - 30% of waste generation. It consists of numerous materials, including,

concrete, bricks, gypsum, wood, glass, metals plastic, solvents, asbestos and excavated soil, many of which can be recycled. According to the latest report on CDW by EU, CDW is 30% of the total waste and 60% of this waste is deposited to landfills. This can be an expensive process in some countries like in UK since 32% of landfill waste comes from construction and demolition of buildings and 13% of products delivered to construction sites are sent directly to landfill without being used [3]. In 1996, Finance Act introduced a tax on waste disposal on all landfill sites registered in UK in order to discourage landfill disposals .

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A study for Australian market found that on the average, about 15% of solid waste landfilled are generated from construction activities annually [4].

Construction and demolition activities generate waste which can be reduced during the construction process. The reduction is not only good for environmental reasons; it could also reduce the overall project cost. A study revealed that the average percentage contribution of building material wastage to project cost overrun is between 21-30% [5].

CDW accounts for approximately 40% of all waste generated in USA [6] which has great opportunity to create closed material loops in a circular economy (CE). Due to an understanding of the needs to minimize waste generated by construction activities, various studies have been carried out to determine both causative factors and preventive measures. This has led to an understanding that construction waste is caused by various activities at design, procurement and construction stages of project lifecycle [7]. There are also other classifications in literature. Building Research Establishment (BRE) of UK defines waste in four stages in the built environment: design, take off/specification, delivery and site waste [8]. Characteristic and universal construction waste types are identified by several organizations including United States Environmental Protection Agency (EPA) and European Union (EU). As a result, special attention is being paid to CDW management at the European level, which is having implications for national-level policies. CDW management is steered in particular by the EU Waste Framework Directive (2008/98/EC), which sets a target for the recycling of non-hazardous CDW at a minimum of 70% of its weight by 2020 [9]. The remaining wastes that cannot be diverted to landfills are collected in a way that separation of items is very difficult so that some valuable components turn into waste (down-cycled). There is a high potential for recycling and re-use of CDW, since some of its components have a high resource value. There is a re-use market for

aggregates derived from CDW in roads, drainage and other construction projects. This research aims to present ways to find out the typical type and amount of waste material in a typical green building project site through Site Waste Management Plans (SWMP). An SWMP should describe how materials will be managed efficiently and disposed of legally during the construction of the works, explaining how the re-use and recycling of materials will be maximised. This involves estimating how much of each type of waste is likely to be produced and the proportion of this that will be re-used or recycled on site, or removed from the site for re-use, recycling, recovery or disposal.

In the light of environmental challenges derived from the current linear economy model of take-make-consume-dispose, the construction industry requires the implementation of new, enhanced building strategies focused on the problem of CDW [10]. The transition to CE helps the construction industry to optimize the use of materials and their value throughout their lifecycle phases, and to minimize waste. CDW is identified in CE policies as a priority [11]. In the European Union, CE has become a central aspect of the development of policies and strategies, as part of the CE Action Plan [12].

Since almost ten years, circular waste treatment programs came into view with extensive consideration, which prior to landfill extracts demolition materials as much as possible for reuse with the aim of zero waste (ZW). The application sources and possibilities of this trend is exposed for Turkish construction circles with the commercialization of more demolished materials for extra economic return. This research aims to present ways and methods to find out the zero waste opportunities in CDW by:

- Identify the waste with the highest CE potential by using a case study
- Modelling sample waste data from 10 green building projects (certified) which are rather randomly distributed by some probabilistic and statistical approaches,

- Identifying the responsibilities of municipalities as policy and decision makers in developing the ZW guidelines in construction sector by using Site Waste Management Plans (SWMP)s.

Identification of waste; in a typical project requested as data in a SWMP covers the non-hazardous waste related to on-site construction and dedicated off-site manufacture or fabrication (including demolition and excavation waste) generated by the building's design and construction. Standard construction projects do not produce SWMPs but they are mandatory for getting green building certification systems.

The case study project selected is a green campus located in western part of Turkey. All buildings on the campus are certified with an international green building certification system. The SWMP data from the project is used as part of this study.

CE priority opportunities of construction waste identified by a study prepared by ZeroWaste Scotland(ZWS) is used as a framework as shown in Table 1. Several different approaches were taken to identifying and prioritizing key intervention opportunities from different perspectives within this framework. A qualitative review of the combined outputs from the three assessments, informed identification of a shortlist of priority opportunities. The comments for Turkey's construction sector are prepared after reviewing the current situation in Turkey by using the same set of shortlist opportunities provided for ZWS.

Materials and Methods

Waste Management

There is a high potential for recycling and re-use of CDW, since some of its components have a high resource value. The amount and type of CDW depends on type of projects, size of the projects, activity performed and construction technology [13]. Other similar study findings also present that volumes, composition and quality of CDW vary between sites, regions and countries, and no general composition can be presented [14,15]. Responsible management of waste is an essential aspect of sustainable buildings. The environmental impacts associated with buildings do not end with their construction,

but continue throughout their use, renovation, and end of life. Building demolition materials at the end of life embody all the upstream impacts associated with delivering and operating buildings, including soil erosion, top soil loss, habitat disruption, natural resource depletion, water and air pollution, climate disruption and land expenditure. International green building certification systems like BREEAM and LEED have criterias, which present the opportunities existing for the beneficial reduction and recovery of materials that would otherwise be destined for disposal as waste during construction stage. Based on the 10 global markets covered by a CBRE report, it is documented that still 18.6% of office space (offices have the highest demand for certification) is certified as green [16]. Despite the increase from just 6.4 % a decade ago, in 2007, most of the new construction market's handling of construction waste in developing countries do not follow a system of minimizing waste despite the existence of laws. To make their business more sustainable, construction companies should consider closed-loop circular design principles as described in Figure 1 and embed them into their product portfolio and business models [17]. Despite the success of green building certification systems for providing solutions for minimizing the construction waste problem, most of the ongoing construction follows the standard construction procedures, when it comes to producing and disposing wastes. A study conducted in Malaysia for formulation of appropriate policy interventions in addressing the construction waste management problem, indicated the importance of procurement of materials, recycling and re-use and rewarding contractors for waste minimization. The study also indicated the importance of government providing guidelines for contractors in implementing waste reduction [18].

Building Activities in Turkey

Turkey's construction industry has developed rapidly since the 1950s with the support of major infrastructure projects and an ongoing urban regeneration plan. In the first quarter of 2018, the construction sector's contribution to economic growth in Turkey was 6,9 %, while the growth in

real estate transactions was 2,9 % and construction investments continued to contribute to the growth of Turkey's economy by 12,3 %. At the same period, there was a growth in the residential, non-residential and infrastructure projects [19]. The problem in many developing countries is the lack of data on construction and demolition waste (CDW) produced [20]. It is reported that there is no net data regarding the amount of construction and demolition wastes in Turkey [21]. As the planned urban transformation projects continue to take place in Turkey, a national system to track and efficiently manage the CDW will be needed.

Construction Project Pipeline

Mega projects are large-scale, complex ventures that typically cost a billion dollars or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people. They are a completely different breed of project in terms of their objectives, lead times, complexity, and stakeholder involvement [22]. Megaprojects may be evolving into giga-projects and even tera-projects in the future meaning more CDW generation. The future of CWD generated for mega projects in developing countries, where green building certifications are not used and a national system does not exist cause waste of resources. Turkey is a growing country with many milestone projects and investments on different areas. The review of Turkey's construction sector identified 1,500+ projects across urban regeneration, social and private housing, commercial, light industrial, education, health campuses, transport, utilities, ports and energy. Turkey's megaprojects are constantly growing ever larger in a long historical trend along with global mega projects like The Hong Kong-Zhuhai-Macau Bridge, Jubail II-Industrial City of Saudi Arabia, Beijing Daxing International Airport, London Crossrail, Dubailand, California High Speed Rail and International Space Station. Turkey will also demolish some of its existing housing stock and develop 6,500 000 housing until 2034 based on Law No. 6306 on restructuring of areas under risk of natural disasters [23]. The estimated CWD to be generated from these projects is

500.000.000 tons [24]. The current annual amount of 45 million tons of CWD in Turkey is estimated to increase to 10 million tons/year. The estimated recycling rate provided by TC Ministry of Environment and Settlements for this amount is 6 million tons/year. There are two types of construction activities creating waste generation. First one creates CDW up to 2 tons described as small-scale and second one creates 2 tons of CDW described as large-scale [25]. Over 100 million tons of CDW were recycled or disposed in 2014 in Turkey [26].

Policies, Laws, Regulations and Incentives

The European Community (EC) Waste Directive mentions under Art 11- 2b that: by 2020, the preparing for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70 % by weight. The Turkey's government has been adopting various measures to reduce waste generation from construction activities along with EC Directives. In accordance with Article 9 of the regulation; excavation, construction and demolition generating facilities are obliged to implement waste management in a way that will minimize the adverse effects of waste on the environment and human health. The first regulation, which is now a law mandates contractors creating CDW to prepare a CDW management plan [25]. The Regulation on Waste Management provides a single comprehensive framework for waste management [26]. However, in the absence of major economic incentives, attempts to significantly promote the recycling behavior may not be easy to drive the requisite behavioral change [27].

Circular Economy Thinking and the Built Environment

The concept of CE is a vibrant subject area in the academic community involving various schools of thought such as cradle to cradle, performance economy, industrial ecology and biomimicry [28]. CE as a concept builds on a mountain of themes relating to waste reduction, recycling,

reuse, material efficiency, security of supply, sustainable consumption and production, better design, sharing of resources etc. as the strands of circular economy thinking [29]. Circular economy thinking in Turkey is still at its infancy. On the other hand, green building movement is transforming standard products to ones with eco labels through the demands of green building certifications used in the market. New strategies to create efficient products are bound to generate an added value to products while others add value to the product of a component (example: buildings). The current economy can be largely described as linear, but a CE is restorative by design, and aims to keep products, components and materials at their highest utility and value, at all times [30]. The CE is about optimizing systems rather than components, which includes careful management of materials in both biological and technical cycles. In technical cycles, materials are maintained, reused, refurbished and (as a last resort) recycled. In biological cycles, non-toxic materials are cascaded and eventually returned to the soil, thus restoring natural capital [30]. There is a limited research on CE within a whole systems context and wide spread practical applications at the product and component level [31]. For example, all green construction projects have waste management plans, but much of the waste is down cycled, where the value, quality and functionality are lower than the original product [32]. CE and business models for this system arising from “design-use-re-use” loop define waste as a resource.

The Zero Waste International Alliance (ZWIA) defined Zero Waste (ZW) as a goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. The revised definition of ZW is conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning and with no discharges to land, water, or air that threaten the environment or human health [33]. The zero waste approach is particularly important in industrial and building processes as it promotes

the full use of industrial or construction inputs in final products or modifying them to better fit other industries or processes without generating waste [34]. Implementing ZW principles is building the circular economy thinking in construction, which is in its infancy. Circular economy thinking means maintaining access to materials and resources for continual and future use. With an ever expanding human population and rising standards of living across the globe, it is likely to be the only viable option to maintain standards of living [35]. The research presents best practices from EU building sector, while drawing a roadmap for developing countries by taking into consideration the risk levels in the net floor area, metal, plastic, paper cardboard, insulation and total wastage. In order to plan the ZW guidelines in the construction sector, the identification of CE opportunities for Turkey’s construction sector has been investigated along with the review of waste credits in LEED and BREEAM certification systems [35, 36].

Green Building Certification Systems

LEED and BREEAM two widely used green building certification systems are used to help the discussion and plan a roadmap for the research. BREEAM is the UK’s Environmental Assessment Method for Buildings, developed by the Building Research Establishment (BRE). The first versions of BREEAM were published in the early 1990’s and since early 2000’s BREEAM is UK Government requirement for publicly funded projects. BREEAM is now an internationally recognized and used system. In 2000, the U.S. Green Building Council (USGBC) established the LEED green building rating system to define and measure green buildings. LEED is an internationally recognized green building certification providing third-party verification that measures how well a building or community performs across the metrics that matter most. The intent of waste credits in green building certification systems like LEED and BREEAM is to provide strategies and tools one needs to develop and implement a successful site waste management plan. There are other international systems and national programs in UK’s like Smart waste [37] and USA International Code Council’s ICC-ES program

[38], ICC's International Green Construction Code (IGCC) [39], National Association of Homebuilders (NAHB) [40] etc. to promote sustainable construction. These programs, some of which include certification components, all incorporate aspects of recycling CDW. In UK BREEAM system, SWMP is prepared describing how materials will be managed efficiently and disposed of legally during the construction of the works. The aim is to promote resource efficiency via the effective management and reduction of construction waste. This involves estimating how much of each waste type is likely to be produced and the proportion of this that will be re-used or recycled on site, or removed from the site for re-use, recycling, recovery or disposal. Since 1st of December 2013, construction sites in England no longer legally require a Site Waste Management Plan (SWMP)

[41]. However, SWMPs are continuing to be used on many projects as best practice or 'minimum standard' by BRE. The plan needs to be prepared at the beginning of the project, before construction, demolition, refurbishment, or maintenance and repairs are undertaken. It must always be prepared before works begin.

In BREEAM, Construction Waste issue is split into two parts: Construction resource efficiency (3 credits), Diversion of resources from landfill (1 credit).

Construction waste groups are sorted according to EU Waste Catalogue [42]. The management of CDW on a site requires the general contractor to document the progress of the plan against the goals laid out on SWMP or compliance documents that needs to be filed. SWMP requires waste to be sorted.

Table 1. Circular Economy Priority Opportunities

Key Opportunities	Shortlist opportunities	Relevance for Turkey's Construction Sector Research and interviews	Potential Impact	
			No impact	Has impact
1	Modular Design	Improvements are needed for Turkey's modular building manufacturing sector.	✓	
2	Circular Timber in Construction	Identification of Certified Timber production need is initiated but not commercialized yet.		✓
3	Circular Aggregates (including concrete, brick, soils and stones)	Turkey is #3 in aggregate production in Europe* but no data for recycled aggregates are available. Recycling to a realistic level, emphasizing the technical implications and environmental and economic limitations of recycling, while examining the necessary conditions for its future potential has to start.		✓
4	Structural Steel and Aluminum Reuse	Limited reuse of structural metals currently occurs. Legal intervention such as reducing taxation on reused products would promote greater reuse.		✓
5	Closed Loop and lean design and construction plasterboard	The full engagement of plasterboard manufacturers to develop recycling practices is needed.		✓
6	Making retrofit and refurbishment	Debate on sustainable retrofits need to start and funded pilot projects needed.		✓

7	Large infrastructure and regeneration projects-circular scoping studies, material banks/reuse hubs	Insert circular strategies into specifications, procurement requirements, tools and processes, etc.	✓
8	Improving building utilization & usage	Incentivize developers to optimize occupancy due to ratable value schemes.	✓

Table 2. European Union summarizing the construction and demolition wastes

Section#	TYPE	Case Study	Assessment of Priority
17 01 01	Concrete		Opportunity 3
17 01 02	Bricks		Opportunity 3
17 01 03	Tiles and ceramics		Opportunity 3
17 02 01	Wood	X	Opportunity 2
17 02 02	Glass	X	
17 02 03	Plastic	X	
17 04 01	copper, bronze, brass	X	
17 04 02	Aluminium	X	Opportunity 4
17 04 03	Lead	X	
17 04 04	Zinc	X	
17 04 05	Iron and steel	X	Opportunity 4
17 04 06	Tin	X	
17 04 07	Mixed metals	X	
17 05 04	Soil and stones (not containing hazardous substances)	X	
17 06 04	Insulation materials (not containing hazardous substances and asbestos)	X	

Table 3. Pilot Project Construction Site Waste Management Plan

WASTE	METAL (kg)		PLASTIC (kg)		PAPER (kg)		INSULATION and other (excavation) (kg)		WOOD (m3)		GLASS (kg)	
	Target	Target	Target	Target	Target	Target	Target	Target	Target	Target	Target	
YEAR 2012												
August					150	160						
September	3466	4000										
October	2033	4000										
November	3720	4000										
November	5200	4000										
November	3744	4000										
November	8525	5000							10725	12240		
December	6449	5000										
YEAR 2013												

January	7433	5000	150	200	200	215			6600	6500
February			350	200					11000	11500
February	4720	5000							27060	27500
March	1220	5000	530	700	650	680			99000	99500
March	3570				520	525				
April	5700	5000	680	7000	1730	1600				
May	1660	4000	980	700	420	380			85800	87000
June	3200	4000	400	500	630	625	16978	18000	312400	314000
July	5100	4000	630	500			12168	13450	369600	370000
August	5042		1230	1300	1530	1600			79200	80000
September	5120		2950	3000	2440	2500			23760	235000
October	2912		1170	1150	1090	1250				3000 3500
November	3445		860	850	750	850				
December	800		940	1000	1130	1180				
TOTAL	78817		9070		9360		29147		1238985	3000
Total Waste (kg)									1,368,379	
Total Recycled waste (kg)									1,339,232	
Recovered from site by a licensed external contractor and recycled.									97,80 %	

Table 4. Waste data for the selected 10 green building projects

Project	Location	Net Floor Area	Metal (kg)	Plastic (kg)	Paper/ Cardboard (kg)	Wood (kg)	Glass (kg)	Insulation and Other (kg)	Concrete	Gypsum
1	TUZLA	24156	78817,43	9070	9360	29148	3000	29147,51	-	-
2	K.ÇEKMECE	30685	95900	479500	93800	-	-	383600	-	-
3	ŞİŞLİ	203384	24280	28750	18850	28700	18410	20900	-	-
4	ATAKÖY	34978	86490	870	5820	1960	900	18100	9420	1050
5	ÇANKAYA	5500	21000	3005	6010	2002	1002	4000	4000	2000
6	GÜNEŞLİ	16240	20000	4000	9000	4000	1	8000	24000	2000
7	MENDERES	17600	89100	1220	1110	-	50	27030	-	-
8	KARŞIYAKA	13029	37760	1000	1500	1000	-	5000	20000	-
9	AFYON	1900	4350	50	1050	-	100	1350	-	-
10	KÜÇÜKYALI	58544	171500	8000	9100	10900	7300	34000	10800	4500

LEED classifies waste management credits under the Materials and Resources (MR) section. The MR credits address all the strategies in the United States Environmental Protection Agency's (EPA) solid waste management hierarchy: reduction, reuse, recycling and waste to energy. LEED has five project types, and each one has different credits for waste management. Alternative daily cover (ADC) does not qualify as material diverted from disposal. Land-clearing debris is not considered construction, demolition, or renovation waste that can contribute to waste diversion. Crushing asphalt, concrete, and

masonry for infill or aggregate is also considered onsite waste diversion. For projects that cannot meet credit requirements using reuse and recycling methods, waste-to-energy systems may be considered waste diversion if the European Commission Waste Framework Directive 2008/98/EC [43] and Waste Incineration Directive 2000/76/EC [44] are followed and Waste to Energy facilities meet applicable European Committee for Standardization (CEN) EN 303 standards [45].

Case Study and methodology

A study prepared by ZeroWaste Scotland (ZWS) is used as a framework for this research which is based on an analysis to identify the following CE priority opportunities. Several different approaches were taken by ZWS analysis to identify and prioritize key intervention opportunities from different perspectives.

A qualitative review of the combined outputs from the three assessments informed identification of a shortlist of priority opportunities. The comments for Turkey's Construction Sector are prepared after Turkey's planned construction, refurbishment and demolition projects to 2025 are identified. By using the same set of shortlist opportunities provided for ZWS, a desk-based review of high impact CE opportunities in the light of the planned construction pipeline is completed as listed in Table 1. Table 2 from EU categorizes the Construction and Demolition Wastes. The waste types corresponding to CE Priority Opportunities are identified. The data from the pilot project's SWMP is gathered and analyzed. The results from the waste management plans can be used to identify and quantify the volume and sort of construction waste. Metal, plastic, paper, insulation and other waste (excavation), wood and glass are the typical waste collected from a construction site as can be seen from the case study. From the collected waste data, with 67% collection rate, metal is found to have the highest potential to be considered for re-use and has a great potential for CE corresponding to opportunity 4. The 12 different waste groups from the case study project provided in SWMP is analyzed for CE opportunities based on the findings presented in Table 2. Based on the data, circular timber in construction, circular aggregates (including concrete, brick, soils and stones) and structural steel and aluminum reuse can be the priorities of CE discussions for construction sector in Turkey.

The "Zero Waste and Climate Change Departments" are planned to be established under Municipalities in Turkey [46] in the near future. They can use the information obtained from this research to prioritize the demolished materials for extra economic return.

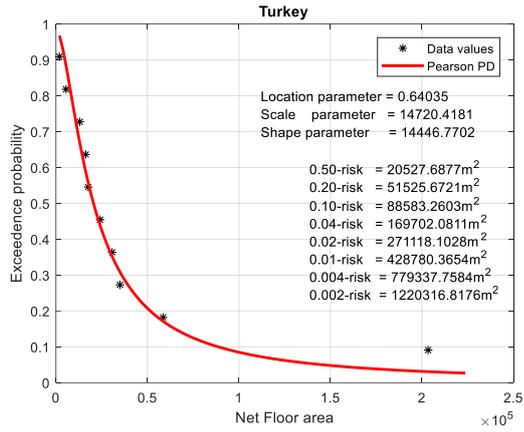
Risk assessment of some Turkish wastes

In Table 3, a pilot project's waste collection variables are shown to fulfill the requirements of a SWMP. The project is located in the western part of Turkey. Table 5 indicates the amounts of total waste and recyclable waste in addition to percentage of recycled waste for each green building project.

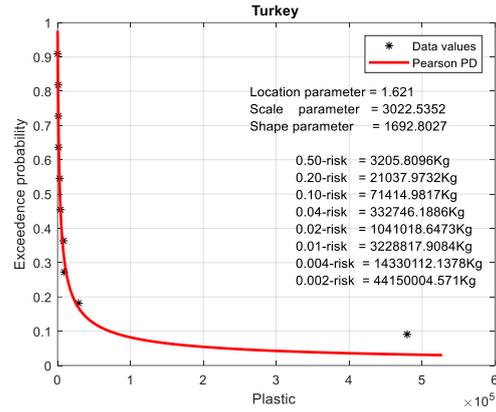
After the scatter diagram of exceedence probability, which represents the risk level, each variable is searched for the best theoretical probability distribution function (PDF). There is no need to present these theoretical PDFs mathematical expressions, which can be found in any textbook on probability and statistics [47, 48]. Figures 3a through 3f present six of these variables, namely, net floor area i.e. space area, metal, plastic, paper cardboard, insulation and total wastage amounts. The PDF models appear as Pearson and Log-normal, types.

Table 5. Recycled Waste

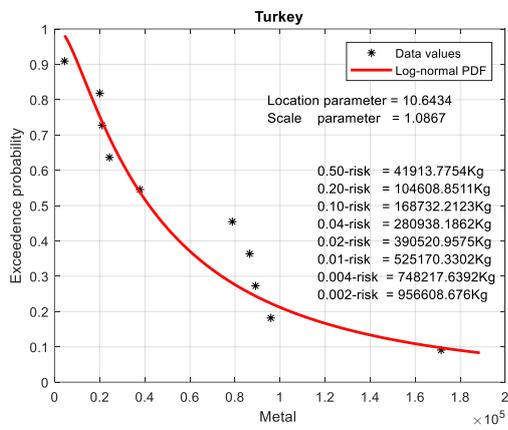
Project	TotalWaste (kg)	Total Recyclable Waste (kg)	% Recycled
1	1368379	1339232	97,87%
2	1052800	669200	63,56%
3	139890	118990	85,06%
4	124610	106510	85,47%
5	43000	37000	86,05%
6	72000	64000	88,89%
7	118510	91480	77,19%
8	66260	57760	87,17%
9	6900	5550	80,43%
10	256100	222100	86,72%



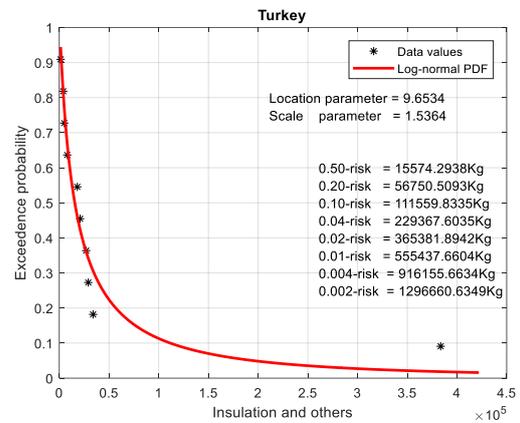
(a)



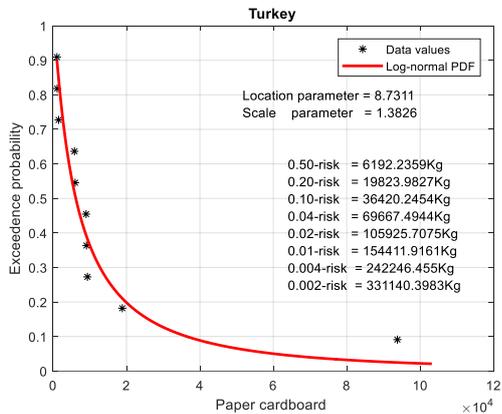
(d)



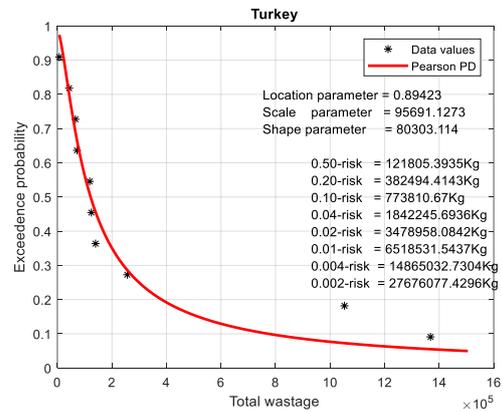
(b)



(e)



(c)



(f)

Figure 3. Risk assessments a) net floor area, b) metal, c) plastic, d) paper cardboard, e) Insulation and Others, f) total Waste

In the same figures the statistical parameters of each PDF are given in addition to the 0.50, 0.20, 0.10, 0.04, 0.02, 0.01, 0.004 and 0.002 risk levels. For the sake of discussion, the PDF graph for total wastage interpretation is given along the following points and similar interpretations can be made for the others.

If the data are for certain duration of time then the risk levels can be associated with time durations,

For instance, provided that the total wastage is per months then, say, 0.50 risk corresponds to the inverse of duration, which is $1/0.5 = 2$ months

and for 0.02 risk level corresponds to $1/0.02 = 50$ -month duration,

The risk level of 0.50 value corresponds to the arithmetic average value.

Conclusions

CDW is the heaviest among waste streams and the amount is growing as the construction sector grows. It consists of numerous materials that can be recycled. For standard projects waste producers are not required to provide accurate data. But construction and demolition waste management data are critical in creating policy and planning for national waste management and reporting.

This study suggests that in countries where a waste reporting system for CDW collection, recycling and disposal do not exist as a national program, the methodologies in widely used international green building certification systems for waste minimization can be used for predict the waste streams. Data obtained from SWMPs developed for green building projects can be used to create risk models and the amount of waste to be generated during a construction can be interpolated. Understanding how much waste is generated during a construction project as well as the types of waste generated for long term storage, disposal, energy recovery and recycling will help local governments in developing the zero waste (ZW) guidelines and national waste reporting in construction sector. As the mathematical model shows, by implementing the suggested methodologies, and using data obtained from SWMPs, waste forecasts for new-

build construction projects can be estimated for properly handling.

Based on the data obtained from pilot projects in this research, circular timber in construction, circular aggregates (including concrete, brick, soils and stones) and structural steel and aluminum reuse can be the priorities of CE discussions in Turkey. From the collected waste data of a green campus project, the metal has the highest collection rate (67%). Once metal enters the material-to-material loop, in which it is recycled many times, it will always be available for future use because it is permanent material. The metal packaging industry is a great example of a circular economy since metal can be recycled forever in a material-to-material loop.

As the planned urban transformation projects continue to take place in Turkey, a national system to track and efficiently manage the CDW data is needed. The optimum levels of waste reduction for re-use and recycling can be achieved through mandatory usage of SWMPs. Once the source control is obtained through use of SWMPs, a circular design and construction standard for reducing CDW can be developed.

Municipalities need to develop strategies to include implementing CDW supervision and management systems to increase circularity. Monitoring the treatment and delivery of CDW among producers, collection, transport and treatment companies are needed. Creating partnerships with government, private sector and NGOs to develop priorities, key barriers and needs also have to be analyzed for future research. Once the standards are in place and barriers obstructing the circular utilization of CDW are presented, commercialization of demolished materials for extra economic return may be fully utilized.

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