



RESEARCH ARTICLE

Construction waste management practices on-sites: A case study of Istanbul city

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ABSTRACT

Increasing construction activities put enormous stress on waste generation in Turkey. Therefore, to manage all these construction wastes by setting effective waste management strategies becomes more significant day by day. Although there is a rising interest in waste management issues, there are not enough studies in Turkey. The lack of data is a prominent obstacle for the researchers. Addressing this research gap, an explanatory multiple-case study was conducted to reveal the waste management practices (waste generation, collection-sorting, storage-disposal, and recovery) on-sites. Unstructured interviews were conducted with different 13 experts working at different construction sites in Istanbul. According to the qualitative study results, there is usually no waste management plan on-sites. Project revisions and cutting of materials for sizing, storage problems are the most emphasized causes of waste on-sites. Wastes are mostly collected and disposed of by the contractors and there is a tendency to collect wastes in mixed on-site and later partly sort. Collection-sorting and storage-disposal practices on-sites are affected by the quantity of waste, site facilities, storage opportunities, scale of the contractor and economic value of waste. The recovery facilities are mostly depending on the economic gain to be obtained from waste. In this context, the recycling and reusing of steel waste is given the best importance. There are not enough networks for recovery of cardboard/paper-plastic wastes on-sites. There is no illegal dumping among the cases included in this study. However, awareness on special treatment of hazardous wastes has not yet been developed enough on-sites in Turkey.

Keywords: Construction waste, waste management, on-site waste management

1. INTRODUCTION

Increasing industrial production activities as parallel to the increase in the world population, alienates human to nature, and causes various environmental impacts such as depletion of natural resources, global warming, non-renewable energy consumption, and waste generation. All these environmental impacts force human to produce solutions and take measures [1, 2]. The construction industry is responsible for an important part of these environmental impacts, such as resource consumption, land use, land deterioration, noise, dust, pollution etc [3]. It is also a major source of urban waste and the most voluminous waste streams generated regularly in urban areas [4]. According to Eurostat data in 2016, construction activities account for approximately 36% of the total waste generated by economic activities and households in Europe [5]. In the last decades, construction activities have

substantially increased due to population growth, economical factors, urban renewal projects, etc, in Turkey. It is estimated that the amount of Construction and Demolition (C&D) waste in Turkey will reach 300 million tons by 2023 [6].

In 2015, the Republic of Turkey Ministry of Environment and Urbanization, in the process of integrating European Union legislation into national law, published "Waste Management Regulation" according to the European Parliament and Council Waste Framework Directive 2008/98/EC. Today, Waste Management activities are executed in accordance with Waste Management Regulation and carried out under the administration and supervision of the Ministry of Environment and Urbanization, Metropolitan Municipalities and municipalities. To set more effective waste management strategies, existing Waste Management Practices (WMP) in 81 provinces were examined by the Ministry of Environment and

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Urbanization, and the improvement proposals related to waste management and the targets to be achieved by 2023 were put forward in National Waste Management and Action Plan. Some of the proposals are to establish a collection system, to implement a vehicle tracking system on vehicles carrying C&D waste, to make selective demolition compulsory to ensure reuse of C&D waste, to establish material definitions and standards about C&D waste, to set a model for the recovery of excavation waste in landscape arrangements and to increase recovery facilities [6]. However, an effective waste management system could not still been established due to some prominent obstacles in application, such as the fact that waste management issue is not a priority policy area, the absence of an established institutional infrastructure authorized at both national and local levels, lack of proper coordination and cooperation among the authorized organizations in waste management, scarcity of resources, inadequate taxes taken for waste collection services, inadequate and limited infrastructure which need modernization, insufficiency of audit and monitoring activities, etc. [7]. C&D waste management research area, however, recently started to attract researchers' interest. Esin and Cosgun [8], conducted a survey aiming to provide some suggestions about preventing and reducing wastes caused by modifications in residential buildings. Polat et al. [9], conducted a quantitative study through a questionnaire survey among Turkish contractors in order to determine the importance level of the waste causes. According to their results, design and construction detail errors, frequent design changes and change orders, waste from cutting uneconomical shape are at high levels of importance as waste causes. Arslan et al. [10], wrote a book chapter about C&D waste management in Turkey. Salgin [11], conducted a study to reveal the strengths and weaknesses of C&D waste management regulations in Turkey. Salgin et al. [12], investigated the benefits of a flexible design in C&D prevention and reduction through a case of an educational building in Kayseri. Salgin [13], additionally, stated that dimensional coordination between building product and building dimensions has an important effect on waste reduction. There is also a study on C&D wastes generated during urban transformation activities in case of Kayseri which is conducted by Salgin and Cosgun [14]. There are also some conference papers conducted by different researchers [15, 16] about C&D waste management practices. However, more research is needed on C&D waste. Lack of data is one of the most important obstacles for the researchers in Turkey. When examined the literature in the World, it is seen that there are various studies ranging from waste quantification, reduction, recovery (reuse, recycle) or disposal, etc. of C&D waste. Most of them focus on C&D waste quantification, characterization, source identification, and recovery or the other management practices separately. Some of them tend to evaluate management practices of the construction industry induced waste itself as a material. The other issues of waste management vary according to the different interests of researchers. There are not much more studies about WMP during construction process. Considering the situation in Turkey and the World, this study presents a process based approach and examines

WMP in the construction process including waste generation, collection-sorting practices, storage-disposal and recovery practices. It also reveals the current applications of CWM practices on-sites and proposes improvement suggestions for the site management practices in Turkey.

2. C&D WASTE

Waste is defined as "any substance or object that the holder discards or intends or is required to discard" [17]. Waste occurs in any industrial production processes. Different production processes cause various types of wastes having different physical, mechanical, chemical, elemental, etc. properties such as being hazardous, inert and non-hazardous. Hazardous wastes are defined as the wastes which have at least one hazard to human health or environment and have the characteristics of hazardous substances such as ignitability, corrosiveness, toxicity or reactivity. Non-hazardous wastes are defined as the wastes having no hazardous features due to the prior physical, chemical and biological transformations. Inert wastes do not experience any physical, chemical and biological transformations [18, 19]. European List of Waste provides a comprehensive classification of wastes according to its compositions and properties [20].

Construction Waste (CW) is defined as "building and site improvement materials and other solid wastes resulting from construction, remodelling, and renovation or repair operations". Demolition waste is defined as "building and site improvement materials resulting from demolition or selective demolition" [19]. CW includes masonry and concrete masonry units, all untreated wood including lumber and finish materials, wood sheet materials, wood trim, metals, roofing insulation carpet and pad, gypsum board, unused (leftover) paint, piping, electrical conduit, packaging such as paper, cardboard, boxes, plastic, sheet and film polystyrene packaging, wood crates, plastic pails, beverage and packaged food containers [19, 21].

Generally, there are produced cleaner materials in the construction process than demolition process [22]. The composition and the effects of C&D waste vary depending on the type of construction and the methods used during construction [23]. According to Gavilan and Bernold [24], the significance of the sources of waste changes depending on the project and material types, and material flow begins with the material delivering process to the disposal of wastes on-site. Approximately 1% to 10% of construction materials on-sites turn into waste [25]. However waste generation rates can be affected different indicators such as the type of building or project being constructed etc. [3]. For instance according to Building Research Establishment's study [26], which was conducted for nine building products at three on-sites (mortar, bricks, concrete roof tiles, concrete blocks, mineral wool, polystyrene, polyurethane insulation panel, plaster and plasterboard), wastage rates differ from 2.1% (mineral wool) to 31.9% (plasterboard).

3. C&D WASTE MANAGEMENT

It is difficult to deal with waste management issues such as collection, storage, transport, treatment, and disposal of wastes, especially in medium and large urban cities. Since 1980, the western world and part of Asia have adopted the waste management hierarchy (WMH) approach [18, 27]. This approach is also known in literature as 3R principle (reduce, recycle, reuse). WMH refers to an order of preference for an action to reduce and manage waste and ranks management activities according to their environmental benefits. Although WMH is a widely used principle, there is no best option from environmental perspective, which has universal consensus [28]. Christensen [27], defined waste management in four phases: Waste generation; Collection and transport; Treatment; Recycling, utilization and land filling (RUL). Waste generation phase consists of waste categories, waste types, waste quantities, and composition. Collection and transport phase includes source separation, collection, transport, and bulk transfer activities. Treatment activities include separation of waste for recovery, incineration, biological treatment, and other operations or processes changing the characteristics of the waste. In the RUL process, waste leaves the system permanently and is recycled, utilized on land (e.g. compost) or in construction, or is disposed of in a landfill [27].

There are many research studies contributed to CW management issues. Gavilan and Bernold [24], conducted a study on categorization and quantification of CW. They classified waste causes into six categories as design, procurement, handling of materials, operation, residual wastes and others not listed. Using the same classification in their study, Bossink and Brouwers [25], conducted a study about causes and generation rates of CW on residential sites. McDonald and Smithers [29] studied the construction process through conducting a case study in Australia. They adapted a waste management plan to reduce the quantity of CW sent to the disposal. Faniran and Caban [30] studied about CW minimization strategies and sources of waste on-sites. Poon et al. [21] conducted a research about on-site sorting of CW. They stated availability of site space is the most important factor which affects construction waste sorting methods. They also found management effort, labour and cost interference with normal site activities as major factors. On the other hand, waste sortability, market for recyclables and environmental benefit are the minor factors of construction waste sorting methods on-sites. Poon et al. [31] analyzed the quantities and causes of waste generated during the construction of residential buildings in Hong Kong and examined waste handling methods. Poon et al. [32] searched the recovery rates of various types of demolition wastes. Poon et al. [33] conducted a questionnaire survey and work site visits aiming to find out cause of waste, to estimate material wastage level and the ways to reduce waste on-sites. Kartam et al. [34] studied C&D wastes through focusing on recycling efforts leading to minimize the wastes sent to the landfill in Kuwait. Shen et al. [35] studied waste handling in construction process through six case studies located in Hong Kong city. Tam and Tam [36] studied recycling practices of CW. Begum et al. [37] conducted a case study to reveal economic

feasibility of CW minimisation on-sites. Osmani et al. [38] studied architects' and contractors' attitudes on waste minimisation through a questionnaire survey. Tam and Tam [39] carried out a study about CW recycling. Tam [40] searched economic considerations about recycling of concrete waste. Osmani et al. [41] investigated architects' approaches about CW minimization through questioners. They have grouped the waste causes according to the origins of waste as contract, design, procurement, transportation, on-site management and planning, material storage, material handling, site operation, residual and others. Tam [42] researched the effectiveness of WMP in construction. Jaillon et al. [43] conducted a study to reveal the waste reduction potential of prefabrication usage compared the conventional construction and found that the prefabrication supplies benefits in waste reduction (approximately 52%) on-sites. Wang et al. [44] conducted a study aiming to find critical success factors for on-site sorting of CW in Chile. Lu and Yuan [45] studied critical success factors for waste management in Chile. Yuan [46] conducted a strength weakness, opportunity and treat analysis for C&D waste management in China. Yuan [47] studied on social performance of C&D waste management and found 8 affecting indicators as practitioners' awareness, provision of job opportunities, physical working conditions, impacts on long-term health, safety of workers, public satisfaction, social image, and public appeal. Yuan et al. [48] searched on-site CW sorting practices through case studies of 6 construction sites Li et al. [49] developed a model for quantifying waste generation in construction. Saez et al. [50] conducted a study about the effectiveness of C&D waste management practices, and they found that the use of industrialized systems and the contract of suppliers managing waste are highly effective practices. Wang et al. [51] presented the critical factors in CW minimization at design stage. Gangolells et al. [52] analyzed implementation of effective WMP in construction site and projects. Bakshan et al. [53] developed a methodology to quantify waste generated at various construction processes. Ajayi et al. [54] conducted a study about site WMP. Ding et al. [55] developed a system dynamic model for waste reduction in construction process. Li et al. [56] searched effecting factors about CW reduction behaviour of contractor employees. Ding et al. [57] developed a model for construction and design stages about waste reduction.

Waste management is not a significant issue in terms of only environment. It should be considered as an economic issue as well. Reducing the amount of waste which is sent to landfill or sent for incineration may supply economic, environmental and social benefits such as creating employment in the recycling industry, reducing the overall building cost, avoiding transportation, new material purchasing and disposal costs, and reducing related environmental impacts such as resource consumption etc. One of the most important benefits of reusing waste materials is the reduction in resource, energy consumption and new material production [47, 58, 59]. According to Begum et al. [37], waste minimization such as reusing and recycling is economically feasible and plays an important role in environmental management.

According to Marzouk and Azab [60], recycling of C&D waste decreases emissions, energy use, global warming potential and conserves landfill and also reduces the costs of combating air pollution.

The variety in the aforementioned studies reveals that waste management is a comprehensive issue focused on quantification, reduction, recovery or disposal of CW, and should be carefully handled in terms of effectively using national material and energy resources and providing environmental and economic sustainability.

4. METHODOLOGY

This study is an explanatory case study which investigates how WMPs are performed on-sites in Istanbul. Explanatory case studies deal with investigating operational process over time instead of frequencies [61]. To increase validity of results, multiple-case study research was conducted among different experts working at different sites in Istanbul. According to Yin [61], multiple-case studies supply to set general explanations which accommodate with each cases even if the cases vary in detail. Multiple-case studies also aim to see processes and outcomes across many cases to understand how they are qualified by the local conditions [62]. The main research questions of the study are as follows:

- What kind of CW are produced on-sites?
- How CW is collected-sorted and stored-disposed on-sites?
- How the CW is recovered (reuse and recycle) on-sites?

The data belonging the cases was collected through unstructured interviews and site visits. The interviews were conducted using a general interview guide approach. Interview guides include a set of topics to be explored, and question sentences are not preset. The questions are asked by the interviewer as the situation evolves [63]. Thus, an unstructured interview guide, in the study, was designed to gather data in a systematic way. It was filled during the interviews, and handwritten notes were taken. The interviews usually continued between 50-80 minutes. Designed interview guide consisted of 3 main sections according to the determined main research questions;

- Main Causes of Waste on-site;
- Collection-Sorting, Storage -Disposal practices of CW on-site;
- Recovery (reuse and recycle) practices.

Data gathering process was completed at two steps:

Firstly, to obtain insights on CWM practices and to reveal the general tendency about CWM practices in Istanbul, a pilot study was conducted through unstructured interviews with 3 different experts working for different sites. The profession and experience of the respondents are given in Table 1.

Table 1. Profession and experience of respondents

Respondent Name	Profession	Site Experience (years)
RA (LsC)	Architect	16
RB (SsC)	Civil engineer	21
RC (LsC)	Architect	28

*R: Respondent, (A, B, C): The codes of the respondents, SsC: Small Scale Contractor, LsC: Large Scale Contractor.

Purposive sampling technique, which means selecting the people, groups or categories on the basis of their relevance to the research questions [64], was used to determine the respondents of the pilot study. To increase generalizability, the respondents were chosen from the experts who have the experiences in small scale construction sites consisting one to three building blocks and large scale construction sites consisting more than three building blocks.

Secondly, the interview guide were updated and detailed according to the pilot study results, and the interviews were conducted with ten different experts for ten different construction sites located in Istanbul. During the interviews, descriptive questions were asked according to the flow of the speech, which facilitated the data acquisition. Seven of the sites were also visited. Interviews and site visits were conducted from May 2018 till April 2019. To overcome the difficulties in finding the respondents willing to attend to the study and to ensure that the respondents involved in the study are at the level of sufficient knowledge and experience, besides purposive sampling, snowball technique was applied. Snowball is a sampling technique which the researcher starts with one sampling category (usually a person) and asks her/him for a new contact to others of a similar or known type [64]. Thus, the respondents working at different construction sites and the different cases have been determined. Of these cases, different types of projects i.e. residential, mixed use, transportation and museum were selected. The cases consisted of three mixed used (office, residential and commercial) projects, five residential projects, one airport project and one museum renewal project. Three of the cases were defined as small scale sites and the remaining cases were defined as large scale sites. General information about the cases and the respondents included in the study is presented in Table 2.

The interviews were conducted with the experts working on totally 10 different cases. The sample size, 10 cases, was decided according to 'theoretical saturation', which means stopping data collection when similar instances are found and there is no new data to reach for the researcher [65].

Additionally, the statements on sample size of the following researchers were also supported this decision. According to Stake [66], the efficiency of the study will be decreased if the number of cases is less than 4 or more than 10. Less than 4 cases do not supply sufficient interactivity whereas 15 or 30 cases show more uniqueness of interactivity which will not be enough clear to understand for researcher team and readers. Guest et al. [67], found data saturation had occurred by the time. They had analyzed twelve

interviews. According to them, a sample of twelve will likely be sufficient to reach saturation. According to Creswell [68], it is typical to study few cases in qualitative research. In some cases, researchers may study a single site and in other cases, the case number

may range 1 or 2 to 30 or 40 cases. Creswell [68] emphasized that a larger number of cases may become unwieldy and time-consuming in terms of collecting and analyzing.

Table 2. General information about the cases and respondents included in the study

Construction Site Number	Function of Construction	Type of Construction	Profession and Site Experience of Respondent (years)
S1*/LsC	Residential-Office (6 Residential Block -8-9 floors, 3 Office Blocks -18 floors)	RCS Façade: Silicon glass and flexible ceramic	Architect 15
S2*/LsC	Residential-Office-Commercial (2 blocks forty-five storey and 1 block with six-storey)	RCS and steel structure	Architect 22
S3*/LsC	Residential (10residential, 1parking and 1social centre blocks)	RCS Façade: Silicon glass and flexible ceramic, aluminium curtain wall system and PVC window frames	Architect 20
S4/SsC	Museum renovation project	Existing museum building constructed as RCS in 1957. Existing building were partly destroyed and RCS and steel beams, composite flooring, strengthening applications in the foundation are applied.	Architect 50
S5*/LsC	Residential (472 villas blocks)	RCS Façade: Heat insulation and plaster	Civil engineer 11
S6/LsC	Airport	Steel Façade: Aluminium panels (The total façade area: 500000 m ²)	Architect 29
S7*/SsC	Residential (3 blocks -14 floors)	RCS Façade: Plaster and paint on rock wool insulation.	Civil engineer 14
S8*/SsC	Residential (1block -14 floors)	RCS	Civil engineer 9
S9/LsC	Residential, 6 blocks	RCS Façade: Aluminium composite panels and stone wool insulation, and plaster	Architect 13
S10*/LsC	Residential-Office-Commercial (9 blocks -15 to 20 floors)	RCS Façade: The precast elements made of glass fibre reinforced concrete and partly ceramic claddings	Chemical engineer 36
Abbreviations	S refers Site, * refers Visited Site, SsC refers Small Scale Contractor, LsC refers Large Scale Contractor RCS refers reinforced concrete structure.		

The analysis of the obtained data was carried out by thematic analysis, which is one of the most common forms of analysis within qualitative research [69]. According to Miles and Huberman [62], data display is "An organised, compressed, assembly of information that permits conclusion drawing and action" According to Alhojailan [70], thematic analysis can be applied to qualitative data when the study aims to reveal the current practices of any individual. According to Braun and Clarke [71], thematic analysis

is the process of analysis of qualitative data through determining patterns or themes. In this strategy, tentative answers for the research questions are categorized into themes which is "a simple sentence, a string of words with a subject and a predicate" [72].

5. RESULTS AND DISCUSSION

In this section, the qualitative data (unstructured interview results) gathered during the pilot study and multiple-cases of CWM practices are analyzed and

discussed. As mentioned in “Methodology Section”, the data analysis is carried out by thematic analysis. According to the thematic analysis, the themes for the data related to the activities carried out during the construction processes of 10 different cases were first determined according to research questions and then given in matrices for all sites. These themes are organized and detailed in relation to waste causes (MC), collection-sorting (C-S), storage (S) and disposal (D), and recovery (R) practices, which are the main sections of the interview guide.

5.1. Main causes of waste on-site

The mostly emphasized waste causes on-sites are presented site by site in Table 3. The interview results and some proposals based on literature review are as follows:

Table 3. Matrix of mostly emphasized waste causes (MC) on-sites

Themes: MC on-sites	Cases (Sites)									
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
MC1. Revisions during construction										
MC2. Intrinsically reasons of the construction process										
(a) Cutting of the materials for sizing										
(b) Temporarily surface protection										
(c) Non-consumables (pallets, packaging)										
MC3. Design and detailing decisions										
(a) Material selection										
(b) Detailing errors										
MC4. Workmanship, assembly and application errors										
MC5. The work coordination and supervision problems										
MC6. Site specific causes										
MC7. Storage conditions and organization problems										
MC8. Mobilization (handling) errors										
MC9. Procurement (over-ordering etc.)										
Affecting Factors: User wishes, Low material resistance, Applied surface area, Project specific orders (Project sized), Designing with standard products, Building in-situ models, Scale of contractor.										

- The main causes of waste in Table 3 were determined and coded considering the interview findings and the classifications of Gavilan and Bernold [24], Bossink and Brouwers [25], Osmani et al. [41]. Special construction projects, however, may cause special wastes, such as the wastes emerged as a result of the protection of some work of art in Site-4. For this reason, unlike other studies, site specific causes (MC6) were handled as another waste cause in this study.

- Project revisions (MC1) and cutting of materials for sizing (MC2-a), storage conditions and organization problems (MC7) are the mostly emphasised causes of wastes on-sites by the respondents. Fig 1 illustrates the waste formed due to cutting of steel reinforcement. According to Polat et al. [9], design and construction detail errors, frequent design changes and change orders, waste from cutting uneconomical shape are at high levels of importance as waste cause. In parallel with the results of Polat et al. [9], project revisions (MC1) and cutting of materials for sizing (MC2-a) are the mostly emphasised causes of wastes on-sites by the

respondents. Faniran and Caban, [21]; Osmani et al., [38] and Poon et al. [33] also confirmed that MC1 and MC2-a are the main generators of waste on-sites.

- In residential projects, MC1 are generally made due to the customer’s esthetical wishes such as a change in the floor or wall finishing materials etc. On the other hand, in commercial spaces, MC1 can be mostly due to the spatial change needs. In addition, some architectural project problems can cause the revisions as well. According to Poon et al. [33], Osmani et al. [38], revisions are made due to last minute client requirements, complex designs, lack of communication between designers, contractors and engineers, lack of design information, unforeseen ground conditions and long project duration. MC1 could be prevented or reduced by developing the coordination between designers and users in design process. Thus users can select themselves finishing materials such as floor coverings, kitchen cupboards etc., in design process and so waste can be avoided.



Fig 1. Waste generation during cutting of steel reinforcement for sizing (Site-8)

- According to Poon et al. [33], designing with standard sized building materials avoids cutting, and also design for flexibility reduces the generation of construction waste. Designing more flexible spaces, especially for commercial spaces, could be another measure to reduce MC1 for Istanbul. To reduce MC2-a, the use of standard products could be widespread for Istanbul.

- There may occur various types of MC2 in relation to construction method (such as in-situ, prefabricated, etc.). According to Jaillon et al. [43], wet trades, such as concreting, masonry etc. usually accounts for 20% of the total wastes on-sites. According to Tam et al. [42], and Jaillon et al. [43], one of the ways of reducing waste due to MC2 is to use prefabricated building components instead of wet trade.

- Usage of materials for temporarily surface protection purposes (MC2-b) is another prominent waste cause. There is usually a tendency on that cardboard, paper and plastic materials to be used for protection purposes are supplied by purchase. However, such materials could be provided from the packaging waste on-sites. According to Jaillon et al. [43], temporary works generate prominent amount of waste on construction sites.

- Non-consumable materials such as wood pallets (M2-c) which is used during transportation of materials, parts or components (MPCs) to site usually turn into waste on-sites. It is possible to reuse these pallets or to recycle in production of different products such as furniture production, etc.

- None of the respondents emphasized use of materials not complying with specifications as an effective waste cause. However, Polat et al. [9] stated that use of materials not complying with specifications is a waste cause at high-medium importance level. According to respondents, if the resistance of selected material is low, there occurs waste due to damage of material during application. However, importance level of material selection (MC3-a) as a waste cause, changes depending on the surface area on which it is applied. For example on Site-1 and 3, there were applied flexible ceramic (having low material resistance) on facade which made MC3-a a prominent waste cause as covering the big surface areas of the buildings. MC3, as proposed in the study of Faniran and Caban [30], can be avoided through some applications such as

reviewing of the project specifications by the contractor at the construction stage, defining the specifications clearly, paying the relevant attention to detailing, design and planning, etc.

- Insufficiency in the supervision of the applications and the change of sub-contractor which causes adaptation problems are the factors affecting the waste generation due to MC4. Following a well-planned work schedule may prevent waste on-sites. Building a model of the detail which will be produced on-sites is another application to prevent waste generation due to MC4. On sites-1, 3, 5, 6 and 9, the models were built in 1/1 scale and applied in situ (Fig 2a-b). According to Yuan [47], practitioners' attitudes directly affect waste generation on-sites, so raising practitioners' awareness is an effective factor in avoiding CW generation due to MC4.

- The work coordination and supervision problems (MC5), such as missing of MPCs on-site and usage of MPCs for different purposes, also cause waste on-sites.

- Waste can occur due to site specific causes (MC6). For instance, on Site-4, during renovation process, some of the paintings exhibited in the museum were temporarily stored on the basement floor and a briquette wall was built around for protection. These walls were then destroyed and turned into waste. The other example is on Site-6. The project delivery time were moved earlier which caused the number of workers working on the roof to increase (200-250 people has reached to 1650 people), and the extra strain on the roof damaged the application. Thus, the application on the roof had to be renewed.

- MC7 is one of the most emphasized waste cause on-sites. To reduce waste resulting from this cause, storage conditions and organization disorders should be avoided. MPCs can deteriorate as a result of storage in unsuitable conditions in the construction site such as high temperature and humidity, windy weather, etc. For instance, gypsum boards may be broken due to the improper storage; insulating boards may be skipped if the prevailing wind direction is not taken into consideration. Storage disorders also may cause waste. For instance, the insulation materials should be placed upright not to be crushed. Mobilization errors (MC8) such as damage to MPCs during horizontal mobilization or damage to MPCs during shipment to the construction site, etc. can cause waste. As parallel

to the proposal of Poon et al. [33], it could be said that supplying coordination between suppliers, designers, manufacturers and contractors could be an effective way to avoid MC8.

- Procurement (MC9) is the least effective waste cause on-sites. As proposed by Poon et al. [33], clear records of purchase, delivery, usage and payment can avoid over-orders and supply material control.



Fig 2. In-situ sample application on Site-1(a) and sample application on Site-3 (b)

5.2. Collection-sorting (C-S), storage (S) and disposal (D) practices on-sites

Collection-sorting (C-S), storage (S) and disposal (D) practices on-sites are presented site by site in Table 4. The interview results and some proposals based on literature review are as follows:

- Wastes are mostly collected and disposed by the contractors (R-a) and there is a tendency to collect waste in mixed on-site and later partly sorted (C-S-b) according to their type (steel, paper, plastic and wood wastes are usually separated). That the contractors are more effective than sub-contractors in waste handling is beneficial in terms of coordination and supervision of the actors involved in the construction process as mentioned by Shen et al. [35]. However, according to respondents, contractors sometimes cause errors during sorting of waste, such as disposing by mistake of any equipment or materials belonging to sub-contractors. According to respondents, C-S is affected by site facilities, storage opportunities, scale of construction, quantity of waste, and economic value of waste.
- LsC firms tend to collect the waste separately or to sort the waste. The quantity of waste is an important factor for waste sorting, especially in small construction sites. If the quantity of waste is little, the constructors usually ignore waste sorting.
- According to the respondents, the economic value of waste is the most substantial factor affecting on CW sorting, differing from Poon et al. [21] which state that availability of site space is the most important factor. For instance, as being a valuable material with high recycling rate, steel waste is the mostly separated waste type on-sites. CS practices of other wastes should be encouraged as well in Turkey. Sorting practices can be increased by educating workers and sub-contractors on waste and these practices, as stated in the study of Poon et al. as well [31], should be a legal or contractual obligation on-sites.

- R_C stated that waste collection period changes site-to-site depending on the production process on-sites, site facilities, and storage opportunities. It should be well planned and organized not to obstacle working conditions. For instance, on-Site-6 (airport), the wastes were sent to the collection area in every 3-4 days. On the other hand, during the production of the roofs, there were generated too much packaging and protection waste (the foils on the aluminum panels caused too much paper and plastic waste.). During the application of the aluminum panels, a team of 100 people collected the wastes to prevent clogging of the gutters.

- Waste storage-disposal practices also changes depending on the site facilities. If there is no place for storage on-site, wastes are sent to landfill without temporarily storage on-site. According to R_C, since the wastes occupy space on-sites, they sometimes make the works difficult. For this reason, the contractor firms generally want the removal of waste from site as soon as possible. This case is similar to the research finding of Poon et al. [31] saying that congested site areas cause obstacles to waste sorting practices on-sites.

- R_A stated that there is a charge of dumping of the waste to landfill determined by the municipalities. The charges are calculated as the cost per a track load. The wastes on all construction sites involved in this study are transferred to the landfill determined by the municipalities (D-a). Hazardous wastes such as bituminous insulating material, and their boxes are usually separated by LsC (S4, 7, 8). SsC generally do not give enough importance to the sorting of hazardous waste. Yuan [47] stated that, illegal dumping of C&D waste also badly affects the city image. However, there is no illegal dumping among the cases included in this study. This shows that there is considerable control mechanism in practice regarding the illegal disposal of waste. On the other hand, any control mechanism on proper disposal of hazardous wastes has not yet been developed enough.

• According to R_A, there are some applications of the burial of the ceramic and concrete wastes on-sites. Burial should be avoided in environmental burden. Incineration (D-b) is forbidden in only two sites

included in the study. Incineration activities should also be avoided in environmental burden on-sites.

Table 4. Collection-sorting (C-S), storage (S) and disposal (D) practices on-sites

Themes: (C-S), (S) and (D) practices on-sites	Cases (Sites)									
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
R. Responsibility										
(a) Waste is collected and disposed by contractor.	■			■	■	■	■	■	■	■
(b) Waste is collected and disposed by subcontractors.		■	■							
C-S. Performing way of waste collection										
(a)Wastes are separately collected and sorted.		■			■	■				■
(b) Wastes are collected and later partly or fully sorted.	■		■				■	■	■	
(c) Wastes are collected in mixed on-site and not sorted.				■						
S. Performing way of storage										
(a) Wastes for disposal are temporarily stored.	■		■	■	■					■
(b) Wastes for disposal are directly sent to landfill.		■					■	■	■	
D. Performing way of disposal										
(a) Wastes are sent to determined landfill areas.	■	■	■	■	■	■	■	■	■	■
(b) Incineration of wastes are forbidden.						■			■	
(c) Special treatment is applied to hazardous wastes.		■	■			■			■	■
Affecting Factors:Quantity of waste, Site facilities, Storage opportunities, Scale of the Contractor, Economic value of waste.										

5.3. Recovery Practices On-Site

Matrix of mostly applied recovery practices (RP) on-sites are presented site by site in Table 5. The interview results and some proposals based on literature review are as follows:

- Waste Management Plan supplies various benefits such as reducing/preventing waste generation, supplying cost savings, reducing risks on-sites, etc. [42]. According to R_A-B-C, there is usually no WMP and RP are usually applied in an unsystematic way on-sites.
- There may be various types of wastes which have the potentiality of reuse and recycling. According to Peng et al. [58], scale of project determines the material reuse and recycling potentiality from economical perspective. According to the interview results; in terms of recovery, the economic gain to be obtained from waste is primarily important for contractors. In this context, recycling of steel waste is given the best importance (RP-a). There are also reuse activities; for instance, steel waste is used in the parapet production on Site-7. According to R_C, any length of steel reinforcement longer than 100-120 cm is suitable for use on-sites. As another example, on Site-1, oriented strand boards which were used in the production of site perimeter were reused as roof sheathing. Similarly, the metal work safety nets were reused in the production of metal profiles. To increase recovery,

MPC's that are temporarily used on-sites should be designed as reusable on same site after the completion of its function. Additionally, the steel beams that were removed from the entrance canopy due to the project revisions were used for floor construction on Site-1 (Fig 3a). On Site-3 (Fig 3b), after the application of floor covering, the remaining cuts of polyethylene sheeting used on slabs were used on window frames as filling materials. The other example is that the aggregate inside the concrete waste was separated, washed and reused in the concrete production on Site-10. Wood pallets were reused through sending back to the supplier on Site-10.

- Wood wastes are generally used as firewood by workers at their home (RP-g, RP-j). However, incineration may cause various impacts threatening human health such as hydrogen chloride, sulphur dioxide, heavy metals (lead, cadmium, dioxins, and particulates) [58]. Incineration applications on-sites should be avoided, and reusing or recycling of wastes should be ensured in environmental burden.
- Cardboard/paper (RP-k), plastic wastes (RP-l) are also among the wastes recycled on-sites. According to R_B, however, there is usually no network for recycling of plastic wastes except municipalities. The recovery of plastic wastes should also be expanded through supplying relevant network.

Table 5. Matrix of mostly applied recovery practices (RP) on-sites

Themes: Recovery Practices (RP) on-sites	Cases (Sites)									
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
RP. Recovery of waste materials										
(a) Steel reinforcement waste is recycled.	■	■	■		■	■	■	■	■	■
(b) Steel reinforcement waste is reused.							■			
(c) Metal pallets are recycled.						■				
(d) Aluminium waste is recycled.	■				■	■				
(e) Galvanized material sheet waste is recycled.						■				
(f) Ceramic/brick/concrete waste is used as a filling.										■
(g) Wood pallets are used for heat recovery.	■	■	■		■	■				
(h) Wood pallets are reused (sent back to the supplier).										■
(j) Wood formwork wastes are used for heat recovery.										■
(k) Cardboard/paper wastes are recycled.	■	■	■		■	■			■	■
(l) Plastic wastes are recycled.	■	■			■	■				■
(m) Polyethylene sheeting waste is reused on windows.			■							
(n) Recovery facilities of waste are ignored.				■						
(o) Excavation waste is used for site arrangements.	■				■					
(p) The aggregate in excavation waste is recovered.							■			
(s) The aggregate inside concrete waste is reused.										
(t) Excavation waste is sent to different sites for reuse.	■									
(u) Over-ordered MPC is sent to different sites for reuse.	■	■					■			
(v) Temporary MPC are used in different productions.	■									
(y) Concrete waste is used temporary site arrangements.										

Affecting Factors: Network with the recycling firms and contractors, Lack of information about recovering potentiality of wastes, Coordination between the sub-processes of construction, Technical teams' and workers' awareness, eagerness and creativity, and Vision and strategy of the contractor firm, Economic gain.

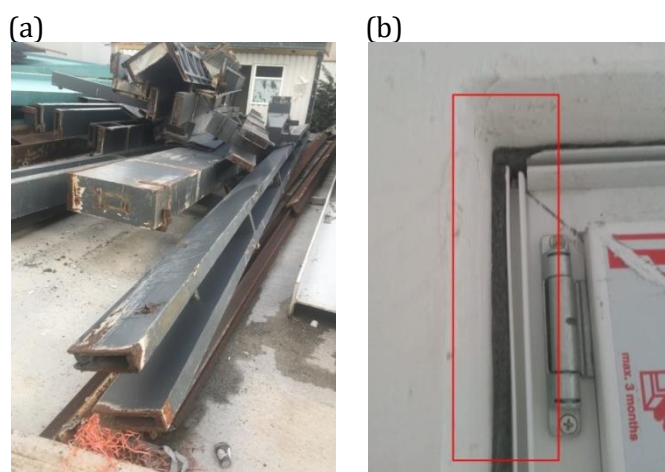


Fig 3. Reused steel beams (Site-1) (a) and polyethylene sheeting used on window frames (Site-3) (b)

• According to R_A, generally, packaged over-ordered MPCs are returned to the supplier. However, it is not possible to return the MPCs ordered in project-specific or block formed materials such as marble. These products usually become directly waste or are kept in

the warehouses by the contractor to reuse at different sites (RP-u). In this case, there may be difficulties about the process of finding and using products from storage, due to the lack of a recording system.

- According to the respondents, although there is usually cooperation between the sites constructed by the same contractor firm, there is not any cooperation among different contractors, which causes a prominent obstacle for recovery of CW on-sites. R_A stated that, recovery of wastes in the construction process where they are produced is very difficult, because the work processes generally do not overlap in construction works. This makes corporation with different sites and contractors important in terms of recovery of waste on-sites.
- Adding to economic value of waste, there are some affecting factors (see Table 5) which may decrease or increase recovery facilities on sites. These are inadequate connections (network) with the recycling firms and contractors, lack of information about recovering potentiality of wastes, coordination between the sub-processes of construction, technical teams' and workers' awareness, eagerness and creativity, and the vision and strategy of the contractor firm. In order to evaluate the reusability of the wastes, (i) a system or network between construction sites and different industries should be developed; (ii) practitioners' (constructors, technical team, workers etc.) awareness should be raised about recovery potentiality of wastes; (iii) coordination between the sub-processes of construction should be supplied. Using this coordination system, the possibility of reuse on the same site (in order to avoid transportation), the possibility of reuse on a different site close to the site and the possibility of reuse in a different production process should be examined and evaluated in environmental burden.

6. CONCLUSIONS

In this study, an overview on C&D waste and waste management was provided and explanatory research was conducted through interviews and site visits to reveal CWM practices on-sites in Istanbul. The study is important in terms of revealing management practices and addressing the issue in a holistic approach, which makes it more prominent from collection to disposal on-sites, differing from many other studies in the literature. The interview results are grouped according to the main sections of the interview guide as; main causes of waste, collection-sorting practices, storage-disposal practices, and recovery practices on-sites. There is usually no waste management plan and management practices are usually applied in an unsystematic way. Project revisions and cutting of materials for sizing and storage conditions and organization problems are the mostly emphasized waste cause on-sites. Coordination between designers and users could be developed and the use of prefabricated components and design with standard sized building materials could be widespread for Turkey. Wastes are mostly collected and disposed by the contractors and there is a tendency to collect waste in mixed on-site and later partly sorted. Well planned and organized separately collection-sorting practices of wastes on-sites should be encouraged for environmental burden. Burial and incineration activities on-sites should be avoided. There is not enough network for recovery of cardboard/paper plastic wastes on-sites, which needs to be developed in

Turkey. There is no illegal dumping among the cases included in this study. However, awareness and control mechanism on special treatment of hazardous wastes has not yet been developed enough on-sites. The economic gain to be obtained from waste is most important factor for contractors. In this context, recycling of steel waste is given the best importance. There are also some reuse activities for steel waste on-site. Besides economic gain, the re-use and recycling of different waste types should be evaluated to achieve environmental benefits. To increase recovery, educational activities for practitioners (constructors, technical team, workers, etc.) should be organized. MPC's that are temporarily used on-sites should also be designed as reusable on same site after the completion of its function.

The construction process consists of different sub-processes. Therefore, different sub-contractors are involved in this process, which makes WMP difficult on-sites. WMP should be applied in a systematic way. To implement more effective WMP for construction sites in Turkey, a holistic approach should be developed which allows all stakeholders assess and decide collectively.

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