Academia Open
Vol 9 No 1 (2024): June . Article type: (Engineering)

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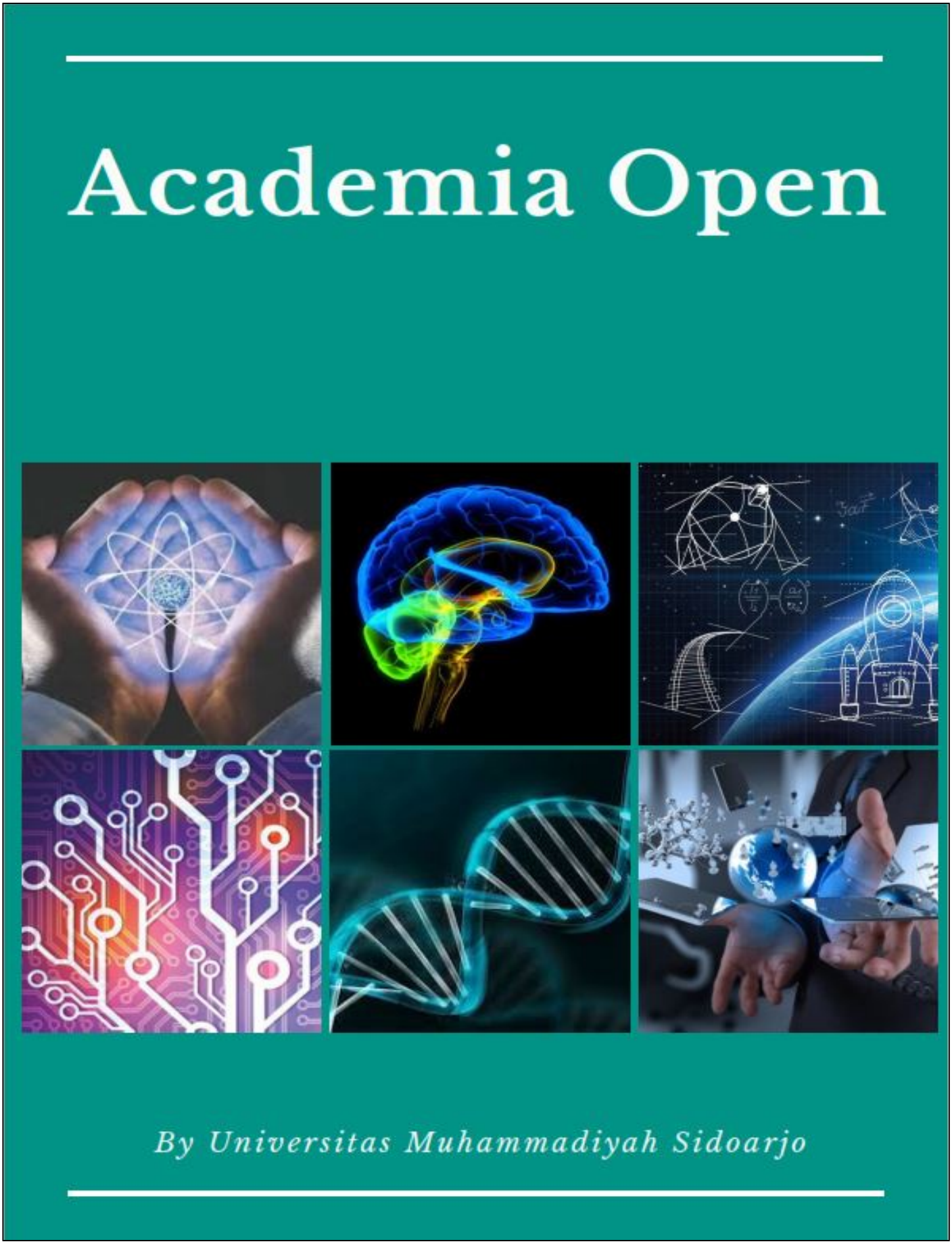

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Academia Open
Vol 9 No 1 (2024): June . Article type: (Engineering)

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Academia Open
Vol 9 No 1 (2024): June . Article type: (Engineering)

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ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

Academia Open
Vol 9 No 1 (2024): June . Article type: (Engineering)

Study of The Application of Construction Waste Management Strategies in The City of Baghdad

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Abstract

This study investigates the effectiveness of construction waste management strategies employed by the Baghdad Municipality Department, with a focus on the spatial distribution of waste treatment facilities. Employing ArcMap 10.8, a geospatial analysis was conducted to evaluate the distribution and accessibility of these facilities within the city. Data on waste treatment site locations were gathered through interviews and Google Earth, and subsequently analyzed using network analysis in ArcMap. The findings reveal a significant deficiency in Baghdad's construction waste management system, predominantly relying on recycling and disposal, while neglecting other crucial strategies like reduction, treatment, and recovery. This insufficiency is further exacerbated by the limited number and uneven distribution of treatment plants, leading to indiscriminate waste accumulation and economic losses. The study suggests the urgent need for comprehensive government regulations on waste management, including waste sorting, transportation, and penalties for non-compliance. Additionally, it recommends expanding and evenly distributing waste treatment facilities across Baghdad to optimize waste management efficiency. This study not only highlights the critical gaps in Baghdad's waste management system but also offers a methodological framework for other cities facing similar challenges, emphasizing the role of geospatial analysis in enhancing urban waste management strategies.

Highlights :

- The study identifies major deficiencies in Baghdad's construction waste management, primarily in recycling and disposal practices.
- Geospatial analysis using ArcMap 10.8 reveals the need for more evenly distributed waste treatment facilities in the city.
- Recommendations include implementing stringent government regulations and expanding the city's waste management infrastructure.

Keywords : Baghdad, Construction Waste Management, Geospatial Analysis, ArcMap, Waste Treatment Facilities

ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

Academia Open
Vol 9 No 1 (2024): June . Article type: (Engineering)

Published date: 2024-01-02 00:00:00

ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

Intoduction

Construction waste is one of the largest sources of waste in the world, and therefore, it is of great interest to stakeholders from governments, investors, contractors, etc.[1]. There are many reasons for generating waste in construction projects, where storage, material handling, transportation, and design are the most important activities that generate waste and drain time and energy[2]. The absence of government standards to control waste and these large quantities caused environmental pollution, depletion of resources, increased energy use, environmental degradation, and loss of biodiversity [3]. Therefore, contractors and the government should consider practical construction and demolition waste management practices[4]. In developed countries, different strategies are used to control construction waste. For example, the European Union is making significant efforts to get rid of the traditional linear waste management system and move to a circular waste management system. The reuse rate in Australia is over 90%[5], in Japan, the reuse rate reached 99.5%[6], Singapore ranked high with a reuse rate of 99.9%, while the recovery rate of construction waste in Malaysia was less than 50% [7]. There is no real waste management system in construction projects in Iraq. There is no clear vision for project managers about the causes of waste generation and how to manage it. In Baghdad, Iraq's cultural and political capital, the entity responsible for managing construction waste is the municipality department represented 3 by the Municipality of Baghdad. The area under its management is 882.9 km2. The municipality has several sites that deal with the generated waste, including two that treat the waste by crushing it to make it suitable for reuse. It also owns (9) transfer stations that deal with waste classified as garbage to be compressed and transported to final landfill sites, in addition to the presence of two approved sites for last landfill outside the governorate’s borders (Interview with the Director of the Debris Treatment Department, Solid Waste and Environment Department/Baghdad Municipality). Most waste treatment sites are located on the city's outskirts and far from construction project sites, and their locations are unknown to project managers[8]. Weakness of waste management system in the city of Baghdad, with a small number of waste treatment plants, in addition to its irregular distribution. In Iraq, there are few previous studies on waste management in construction projects[9]. Despite the valuable efforts made to provide solutions for effective waste management, the continued generation of waste from construction work confirms that these solutions are not sufficient to reduce this waste[10].

This study aims to focus on the strategies used by the Baghdad Municipality Department to manage construction waste and distribute waste treatment plants.

ArcMap software is used to study the distribution of construction waste treatment plants. ArcMap is the main mapping application which allows you to create maps, query attributes, analyze spatial relationships, and layout final projects, this application is produced by the Environmental Systems Research Institute (ESRI), ArcMap represents geographic information as a collection of layers and other elements in a map view, there are two primary map views in ArcMap: data view and Layout view. The map created in ArcMap will be saved as a file on disk[11]. The ArcMap version 10.8 is used in this study. The user interface of this software includes a table of contents, menu bar, tools toolbar, draw toolbar, standard toolbar, layout modes, display window, and Arc Toolbox, refer to Figure (1).

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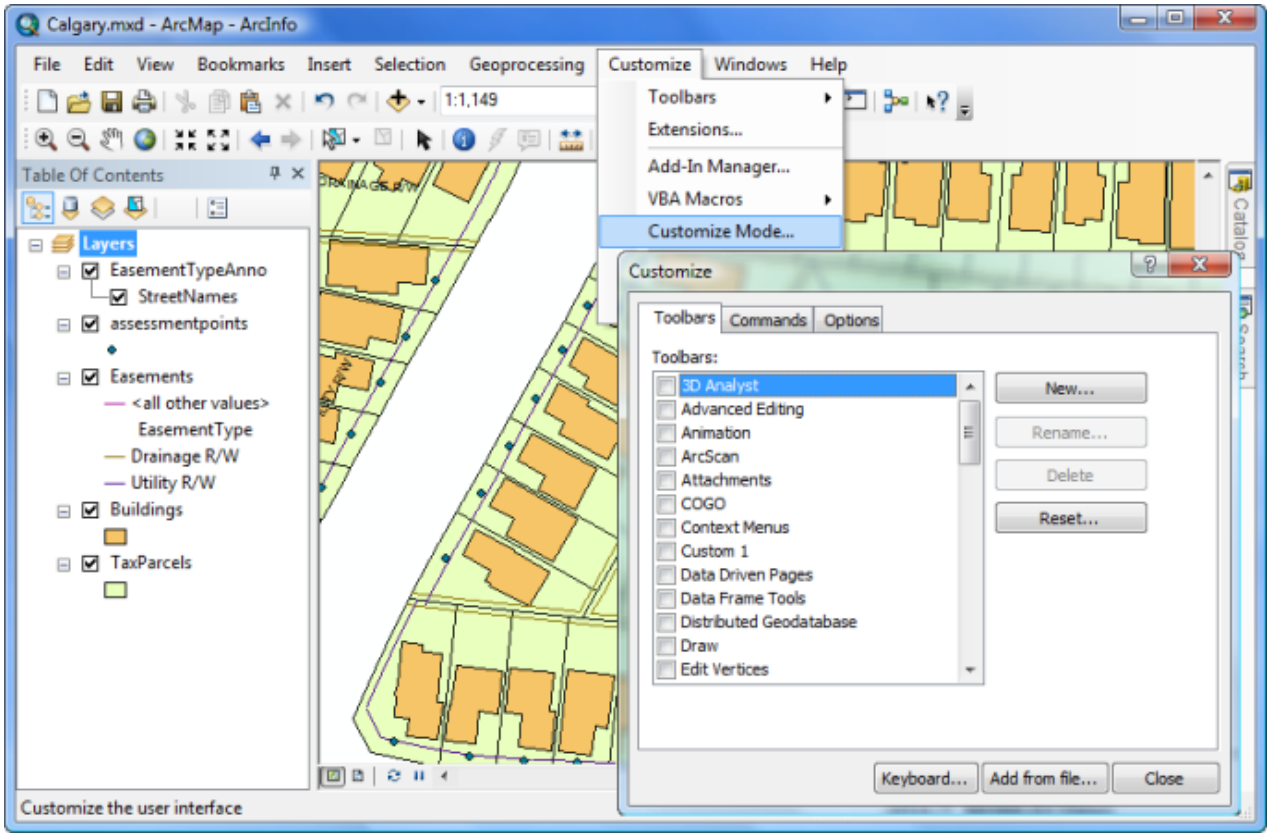

Figure 1. *ArcMap User Interface[11]*

CWM Strategies

3R technology is one of the lean management tools that divides construction and demolition waste management strategies into three principles: reduce, reuse and recycle [12]. Other studies reported four strategies: reduce, reuse, recycle and recover. One of the previous studies indicated that the construction and demolition waste management strategies consist of five principles: reduce, reuse, recycle, return and reprocess[13]. The most comprehensive division is the waste hierarchy composed of

six steps: reduce, reuse, recycle, recover, treat, and dispose as shown in Figure (2). Waste reduction is the best option, while disposal is the worst[14]

The current study agrees with the latest construction waste management strategies classification because it is more comprehensive. Still, with the addition of another principle, which is the principle of estimating construction waste, this principle is fundamental. It will facilitate the management of the correct response to waste if it occurs because it is pre-estimated. Thus, the construction waste management strategies consist of seven steps: estimation, reduce, reuse, recycle, recover, treat and dispose.

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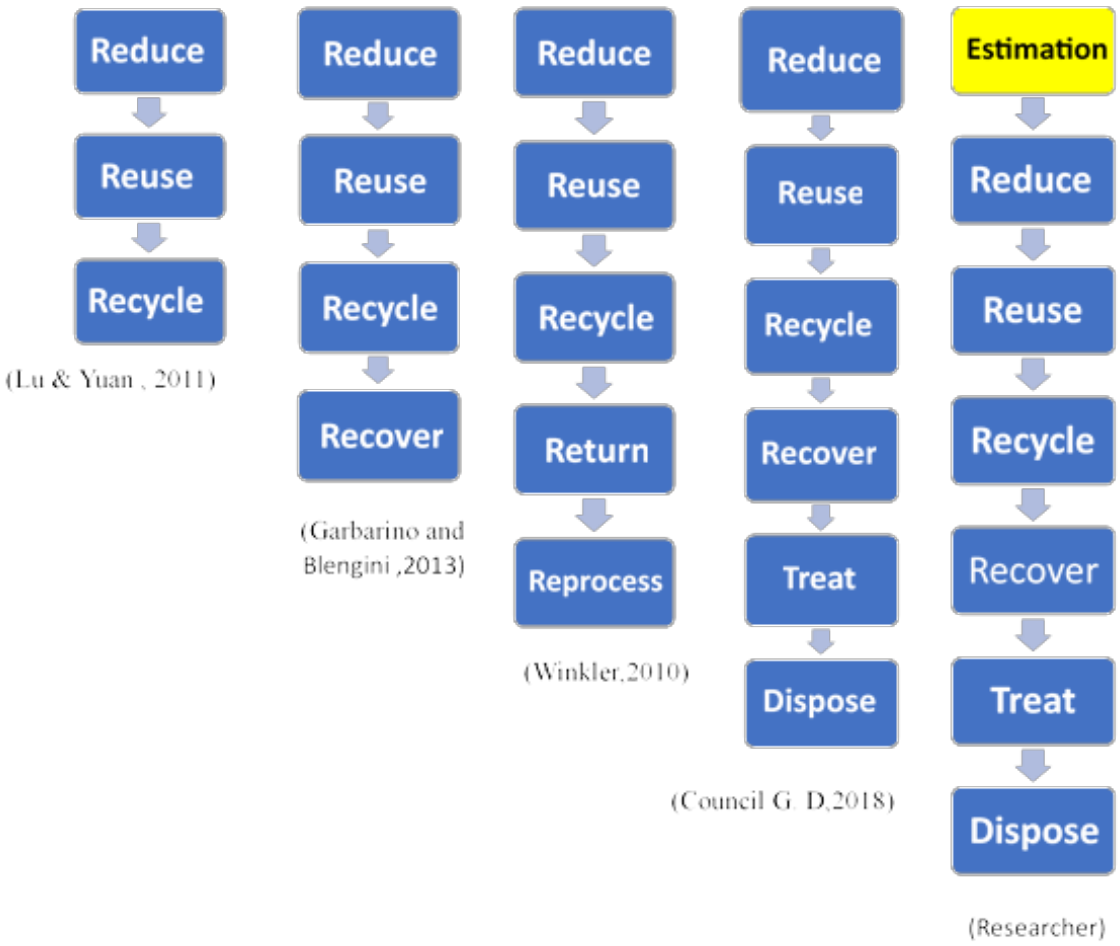

Figure 2. *CWM strategies*

Estimation

Accurate assessment of construction waste in the design phase before it is generated in the implementation phase of various construction and demolition projects is a prerequisite for effective management. Through accurate waste estimation, construction companies can determine the categories of these wastes, identify the essential types of materials that generate more waste, and track the origins of these waste streams, Thus, it is possible to determine which construction process produces more waste and requires more attention, and the possibility of using appropriate construction techniques and methods and using more sustainable alternatives to improve performance and increase the quality of construction waste management.

Reducing

The term construction waste reduction (CWR) refers to reducing the waste generated during the construction process to the lowest possible level, which reduces the effects of these generated wastes on the environment and increases the sustainability of the construction process. There is no focus on reduction management in many countries[15] because there are several barriers.

This study pointed out some of the benefits of reduction, such as reducing costs by purchasing fewer materials, reducing carbon dioxide emissions, and reducing the cost of transporting waste to private landfills. Therefore, reduction is the best environmental solution in addition to being cost-effective, as shown in Figure (3).

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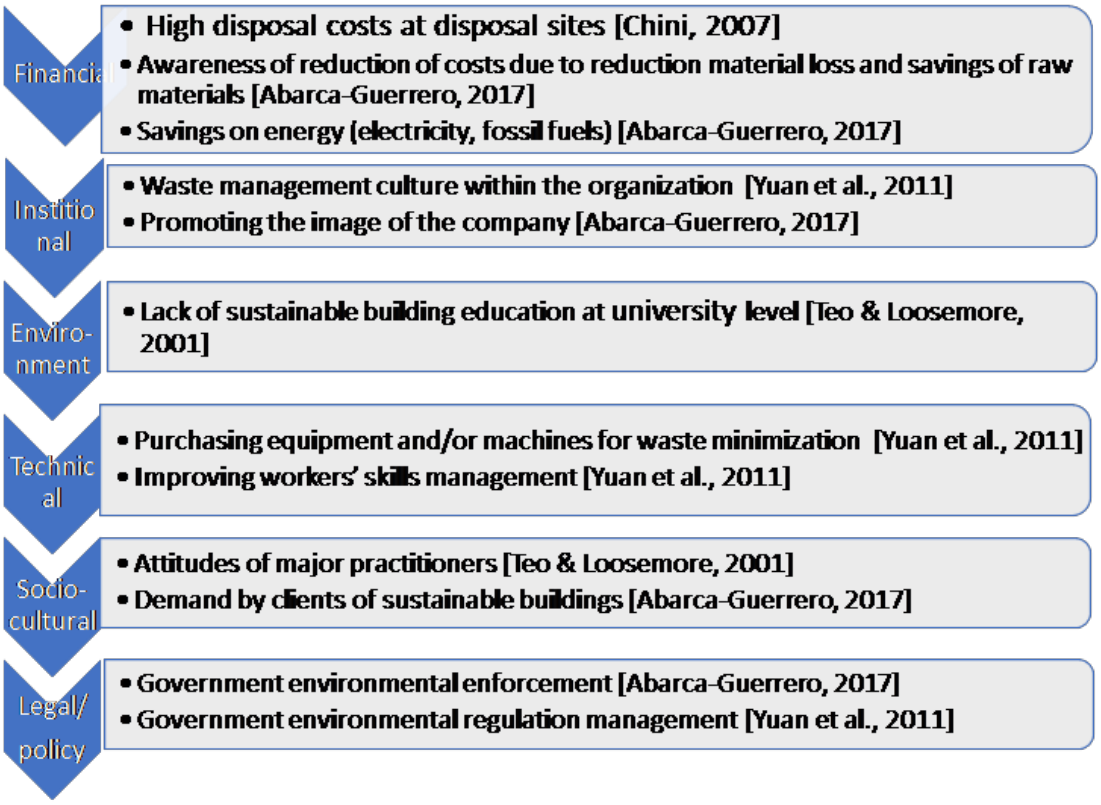

Figure 3. *Motivations to implement reduction of CW*

Reusing

There is agreement in the literature that adopting a reuse strategy has a critical role in optimizing waste minimization [16]. Reuse saves energy and processing[17]. Therefore, reuse is one of the most effective activities to preserve the environment and natural materials, as it reduces the amount of waste that is transported and disposed of in construction waste burial sites[16]. Typical materials suitable for reuse include bricks, doors, windows, cabinets, roofing tiles, wood, flooring, etc. [18] The reuse of waste represents an economic benefit in the range of 5% to 10% of the cost of the total value of the project materials[19].

Recycling

Construction waste recycling is an indispensable component of a comprehensive waste management strategy[20]. Therefore, effective waste management presses to reduce the impact of waste to the lowest possible extent, as recycling is considered one of the successful tools for recovering that waste[21]. There are a lot of benefits to recycling, as shown in Figure (4). There are a lot of approved recycling plans, but the actual management of recycling is limited to a few types of waste because recycling requires taking into account three main areas[22] :

1. Material properties
2. Economy
3. Compatibility with other materials

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Figure 4. *Important benefits of Recycling*

Many techniques are used to recycle different types of waste, as shown in Table (1). Economically, the waste recycling process is preferred only if the recycled product is competitive with natural resources in terms of quantity and cost, and this matter spreads in areas where raw materials are fewer and fewer Landfill sites[21].

C&D materials	Recycling technology	Recycled product
Asphalt	Cold recycling Heat generation Minnesota process Parallel drum process Elongated drum Microwave asphalt recycling system Finfalt Surface regeneration	Recycled asphalt Asphalt aggregate
Brick	Burn to ash Crush into aggregate	Slime burnt ash Filling material Hardcore
Concrete	Crush into aggregate	Recycled aggregate Cement replacement (replace the cement by the fine portion of demolished concrete) Protection of levee Backfilling Filler
Ferrous metal	Melt Reuse directly	Recycled steel scrap
Masonry	Crush into aggregate Heat to 900 ◦C to ash	Thermal insulating concrete Traditional clay brick Sodium silicate brick
Non-ferrous metal	Melt	Recycled metal
Paper and cardboard	Purification	Recycled paper
C&D materials	Recycling technology	Recycled product
Glass	Reuse directly Grind to powder Polishing Crush into aggregate Burn to ash	Recycled window unit Glass fiber Filling material Tile Paving block Asphalt Recycled aggregate Cement replacement Man-made soil
Plastic	Convert to powder by cryogenic milling Clipping Crush into aggregate Burn to ash	Panel Recycled plastic Plastic lumber Recycled aggregate Landfill drainage Asphalt Man-made soil
Timber	Reuse directly Cut into aggregate Blast furnace deoxidization Gasification or pyrolysis Chipping Molding by pressurizing timber chip	Whole timber Furniture and kitchen utensilsLightweight recycled aggregate Source of energy Chemical production Wood-based panel Plastic

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	under steam and water	lumber Geofabric Insulation board

Table 1. *Technology of material recycling practices*

Recover

For long periods, dumping waste in sanitary landfills was the traditional method followed by project managers in dealing with waste. Still, with a shortage of landfill space, which has become evident in recent years, the circular economy is the solution to address this problem. circular economy is an economic system that replaces the end-of-life concept of business models with the concept of reduce, reuse, recycle and recover[23]. Recovery is an essential component of the waste management hierarchy because of the associated economic and environmental benefits such as pollution reduction and raw material conservation[24]. This principle agrees with the belief of advocates of the circular economy, who consider waste recovery as a process high in the waste hierarchy, using which energy, as shown in Figure (2. 11) and raw materials are conserved in the economy[25].

Treatment

Over the past fifty years, waste treatment systems have been developed. Waste collection, landfilling, incineration, and wastewater treatment practices have become standard practices in industries worldwide[26].Choosing the appropriate waste treatment technology is a multi-criteria decision-making process[27]. Waste treatment thermally can produce energy, the amount of electrical energy generated from the waste treatment process and the production of combustion gas by different technologies and compared with the amount of energy generated from recycling[28].

Disposing

Although all available methods have been used to encourage waste reduction, reuse and recycling, landfill disposal, the last option in the waste management hierarchy, remains the most common method in the construction industry[29]. Three main factors must be controlled at a high level to obtain safe disposal of construction waste. These factors include tracking and scheduling construction waste, road management and transportation collection, and identifying and accounting for illegal waste dumps, choosing the shortest transportation route is the most applicable element among the three factors[30]. Choose a more straightforward way not because of the cost of transportation but only for other problems such as dyeing the dust and the dirt, sand, lime and others, adversely affecting the appearance of the city and its natural landscapes[31].There are two ways to dispose of waste.

Method

Transporting construction waste from its generation site to the nearest waste treatment site is the problem around which the content of this study revolves. Baghdad city boundaries and coordinates of waste treatment sites in Baghdad city were downloaded using Google Earth. The coordinates of the treatment sites were obtained through a direct interview with the director of debris treatment, department in the Solid Waste and Environment Department of the Baghdad Municipality. Table (2) shows details of the recorded data. The data was then exported to Arcmap to perform network analysis.

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Crusher A	Crusher of Al-Shamaya/Al-Rashad	33°23'10.2"N 44°29'55.7"E
Crusher B	Crusherof Al-Rasheed/Heritage	33°13'15.3"N 44°22'20.3"E
Station A	Rusafa compactor station	33°20'28.7"N 44°27'35.9"E
Station B	Kasra & Atash compactor station	33°24'42.31"N 44°26'50.21"E
Station C	Al-Sadr City First compactor station	33°20'59.34"N 44°26'50.45"E
Station D	Al-Ghadeer compactor station	33°22'2.78"N 44°28'50.96"E
Station E	Karrada compactor station	33°18'00.2"N 44°27'55.3"E
Station F	Al-Shuala compactor station	33°23'29.25"N 44°17'10.13"E
Station G	Al-Mansour compactor station	33°18'27.53"N 44°16'43.22"E
Station H	Al-Dora compactor station	33°13'32.96"N 44°22'32.05"E
Station I	Al-Bayaa compactor station	33°15'35.73"N 44°20'21.22"E
Landfill 1	Al-Nahrawan site	33°20'8.45"N 44°52'46.77"E
Landfill 2	Al-Nabai site	33°30'43.77"N 44°14'28.30"E
Landfill 3	Al-Boaitha site	33°12'12.77"N 44°26'18.39"E

Figure 5. *Table 2: Details of the recorded data*

[Dept. of Solid Waste and Environment]

Result and Discussions

Services Area

This analysis is one of the most essential network analyses through which the area covered by the service center can be determined.

Service Area of Crusher

The Area Service New analysis is selected by clicking on the network analysis tools icon, and the distances are determined as (5km, 10km, 15km, and 20km) to clarify the areas that are far from the crushers according to these distances shown in Figure (5).

Figure (5): Choosing distance of Services area [Researcher]

After that, the locations of the crushers as Facilities are chosen, and the Solve command is given, Figure (5.21) shows the results, where the colors (yellow, hazel, pink, red, and white) indicate the areas that are at a distance of (5km, 10km, 15km, 20km, and more than 20 km), respectively, from the closest crusher site in Baghdad.

It is noted from Figure (6) that more than half of the areas of the city of Baghdad is 20 km away from the quarries and more, including vital areas located in the middle of the capital. This is normal because the number of quarries is only two, and this number cannot cover the large size of Baghdad, which is estimated at 204.2 km^2. Therefore, more quarries should be established by the Municipality of the Capital, especially in the northwestern part of the city.

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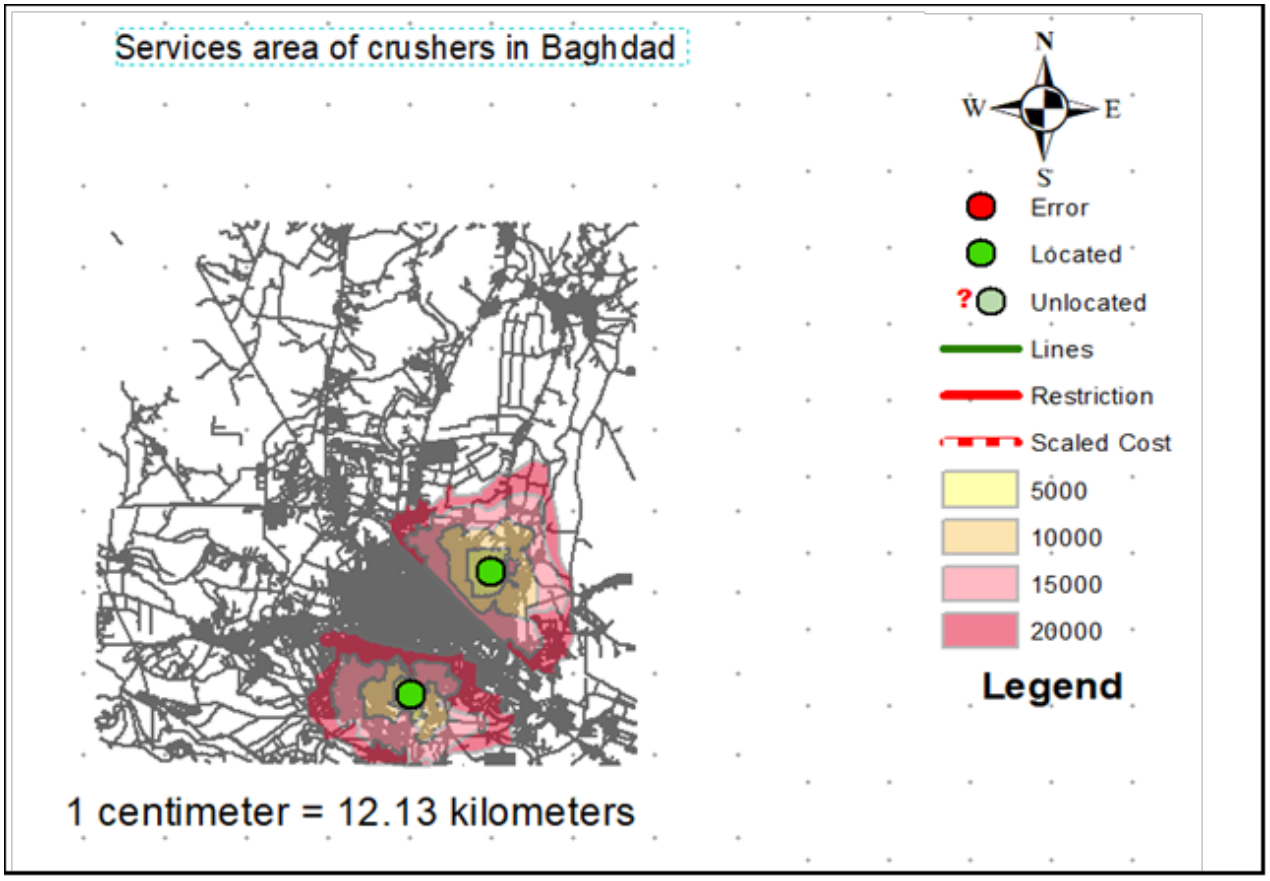

Figure 6. *Services area of crushers in Baghdad [Researcher]*

Service Area of Waste Compactor

The same previous steps are repeated, as Figure (7) shows the results.

It is noted from Figure (5.22) that there are nine waste compaction stations in the city of Baghdad. Despite the relatively large number of stations, their distribution could be more practical. It is clear from the figure that there is overlap in some areas, as it is served by more than one station, while there are areas with a station closest to it that is not less than 15 km in distance, as shown for the pink, red and white spaces. Therefore, Baghdad needs to establish more waste treatment plants by compacting.

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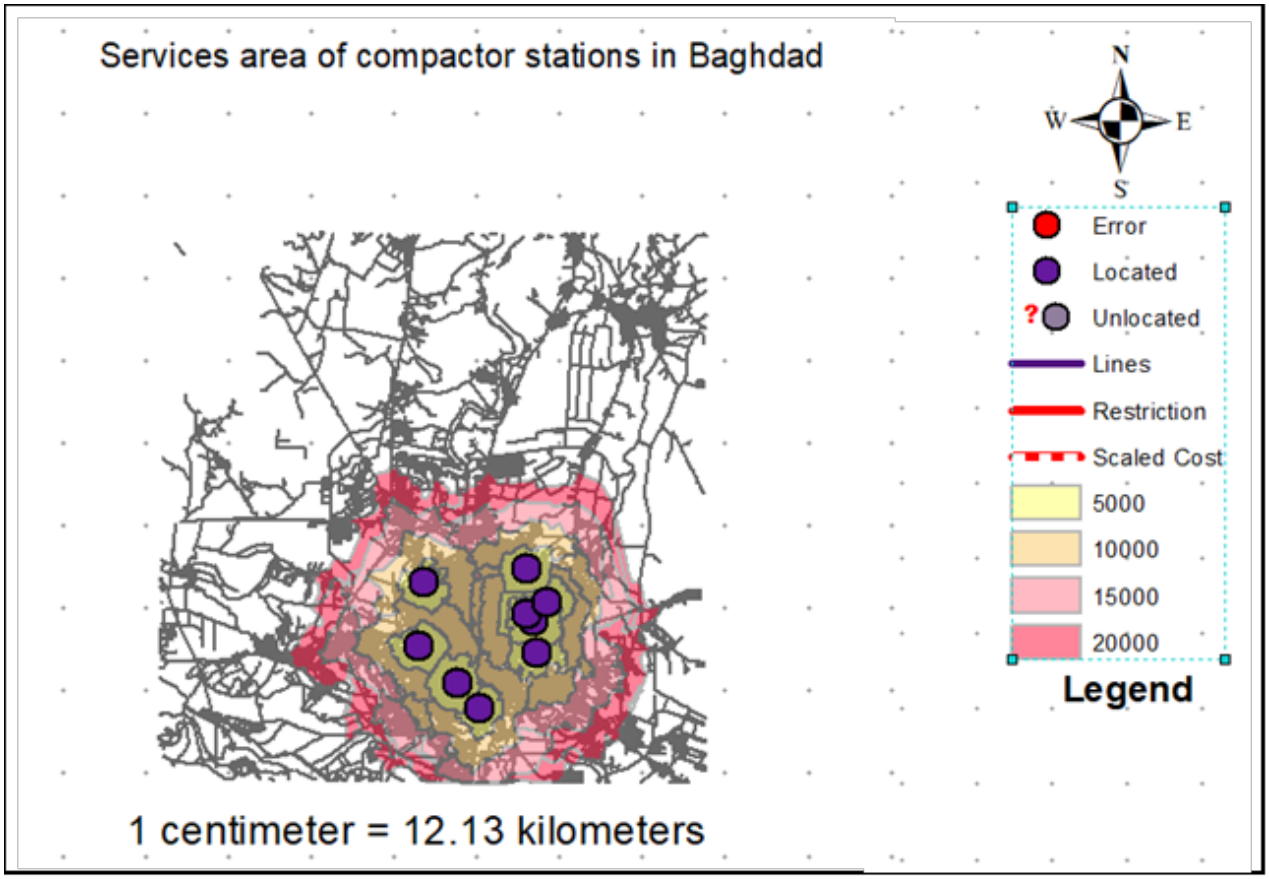

Figure 7. *Services area of compactor stations in Baghdad [Researcher]*

Service Area of Landfill

The same previous steps are repeated, but the distances are changed, and a higher tolerance is given because the landfill site is located outside the cities, where the following spaces are provided (20km, 35, 50km), in colors (yellow, pink, red, and white) respectively, as shown in Figure (8)

It is noted from Figure (5.23) that there are three final landfill sites in the city of Baghdad. These sites are located on the city's outskirts and far from residential areas, which is expected because of its health and environmental risks. Because of the far distance from the city, project managers or municipal officials must use large-capacity vehicles to transport waste to landfill sites to reduce costs.

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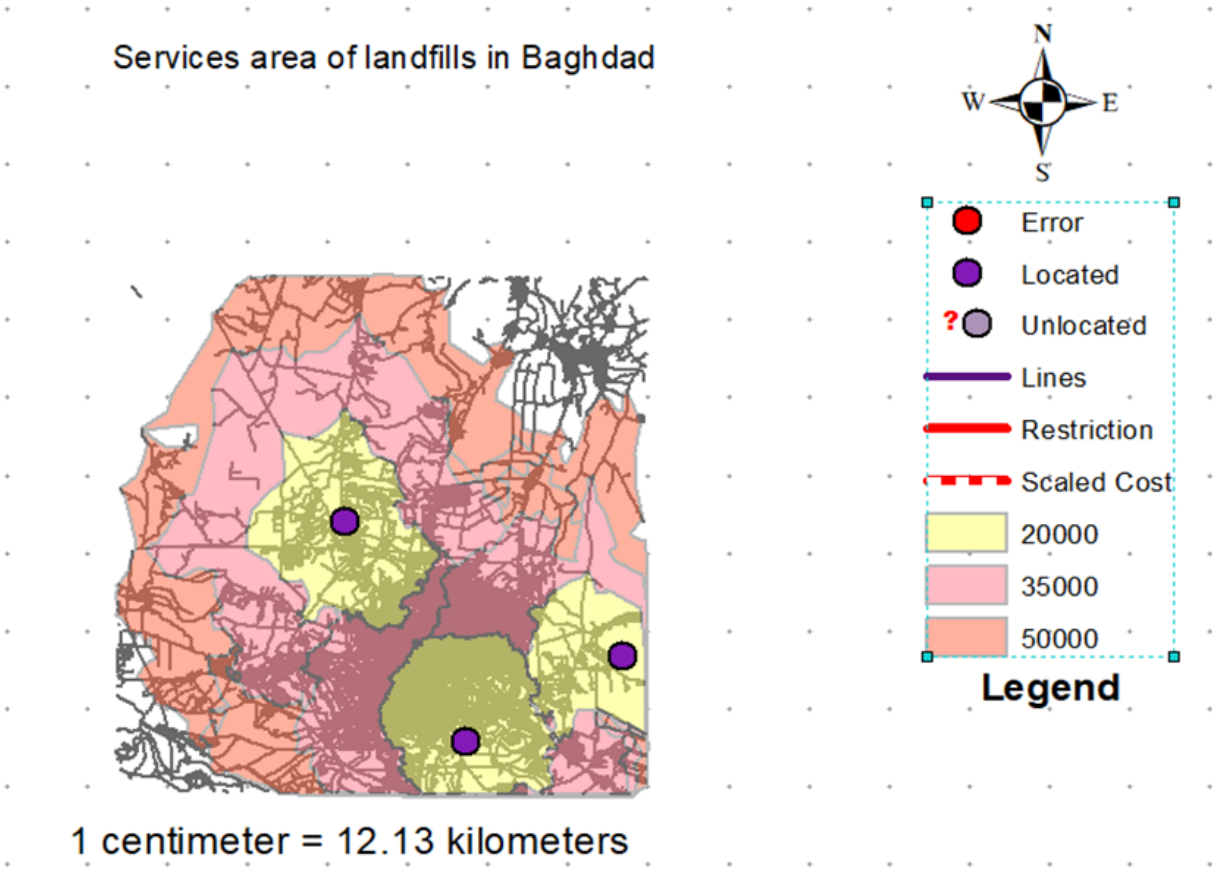

Figure 8. *Services area of landfills in Baghdad [Researcher)*

Conclusion

The results of this study confirmed the weakness of the waste management system in the city of Baghdad, as the municipality relies on only a few strategies, namely recycling and disposal, leaving other important strategies for reduction, treatment, and recovery. With the small number of treatment plants and their irregular distribution, which explains the reason for the random accumulation of waste on the sides of roads and in front of construction projects, which led to the random accumulation of waste with an economic loss resulting from not exploiting these large quantities of waste. This study recommends enacting government laws that regulate the process of waste management, including the necessity of sorting and transporting it to specific treatment sites, and imposing fines for randomly throwing waste. Building additional waste treatment plants in Baghdad, especially crushing plants, and distributing them on a regular basis to ensure coverage of the entire city area. This network can be used for further analysis, such as adding processing centers, construction laboratory centers, and others.

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