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Research Article

Waste Management Planning using Zero-Waste Approach at University-X in Abu Dhabi, U.A.E.

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ABSTRACT

The transition towards a circular economy has received massive attention because of the economic benefits and sustainable living goals. The main objective of this paper is to apply environmentally sustainable methods to the waste management system at the university's campus and minimize waste transferred to landfills. The current waste management system was evaluated based on Strengths, Weaknesses, Opportunities, and Threats (SWOT). The load count analysis recorded an average of 12 tons of waste produced per day in the study area, categorized as 12% wastepaper, 13% plastics and metals, 64% bio waste, 1% glass, and 10% mixed. The findings of the calculations of the Zero-Waste Index (Z.W.I.) for the current waste management (Scenario 1) and after applying the zero-waste approach (Scenario 2) were 0.61 and 0.72, respectively. In addition, the substitution values of the resource (SFi) from waste management systems for the Z.W.I. showed that the approach would result in daily substitution of virgin materials amounting to 8.59 tons, energy substitution of 137.89 MJ/ton, Greenhouses Gases (GHG) emissions reduction of 14.76 CO2e/ton, and water savings of 2.11 L. The Z.W.I. difference is insignificant due to the high generation of bio waste, which troubles material recovery. To sum up, this approach will help decrease the university's ecological footprint and create economic benefits. Additionally, this study highlights the strengths and weaknesses of the waste management system and lays the foundation for the needed improvement.

Keywords: Zero-waste; Waste management; Waste categorization; Sustainable development; Circular economy

INTRODUCTION

The United Nations defines waste as: "materials that are not prime products (that is, products produced for the market) for which the generator has no further use in terms of their purposes of production transformation or consumption, and of which they want to dispose. Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities" [1]. Waste generation is a significant issue on a global scale, particularly with the alarmingly increasing rate that is in lockstep with the world's population and living standards. In addition, the environmental impacts are massive, with only primary or minor treatments to mitigate the harm.

In the recent decade, waste volumes in the U.A.E. have grown due to population expansion and economic activities. The majority of the waste is disposed of in municipal landfills or dumpsites, where the discarded have the probability of producing significant quantities of greenhouse gases including methane. Local authorities are in charge of waste management throughout the country, so this helps in the U.A.E.'s goal of minimizing cities' negative environmental impacts per inhabitant, with a focus on air quality and waste management [2].

Zero-waste is defined as the conversation 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 [3]. While recycling and appropriate waste management are essential to reaching that objective, zero-waste encompasses more than dealing with "end-of-life" waste but at the product's or material's full life cycle, revealing inefficiencies and unsustainable manufacturing and consumption patterns. Landfills can no longer retain our waste and the recycling sector cannot

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keep up with demand at present levels of waste generation. While recycling is critical to the zero-waste movement, it should not be overused.

This study will detail the possibility of applying a zero-waste initiative in a hypothetical university building located in Al Ain region of the Emirate of Abu Dhabi in the United Arab Emirates. For confidentiality purposes, data attributing to an actual campus in Al Ain region could not be used. Assumptions were made using worldwide standards for waste generation and waste characterization. Other analytical information about the university needed to perform the required calculations and analysis was made with respect to the demographic characteristics of the region of the study.

The significance of the study resembles the economic vision 2030 of Abu Dhabi which aspires to transform the economy's foundation away from natural sources and towards knowledge, innovation, sustainable living, and the export of cutting-edge technology. The study was conducted to answer the following research questions:

RQ1. How to decrease the rate of waste generation in the U.A.E.?

RQ2. Is the Zero-Waste initiative applicable in the U.A.E.?

RQ3. What do we need to successfully apply the zero-waste initiative on the theoretical university campus?

METHODOLOGY

The model that will be used to do the study is a theoretical model of a university campus built in Al Ain region and will be referred to as 'University-X' and/or 'the university' in the report. As the first assumption, the university will be thought of as a private university that has been functioning for 15 years and that it includes five different colleges. The location of the theoretical university campus is in 'Al Muwaij'i' area which incorporates most of Al Ain schools with a total campus area of 42,478 meters squared. With the socio-demographics in mind, the university is thought to be enrolling a total of 10,000 students and a total of 700 working as faculty members, instructors, and administrative personnel. Another important assumption was taken from the 'department of energy and environmental protection' in connecticut for the average college student's annual waste generation which was recorded at 290.3 Kg.

It has been decided that waste is collected from five different areas which are: dormitories buildings, food court, playgrounds and roads, academic areas, and laboratories buildings. Because of confidentiality purposes, the categorization of waste from another study was used as a reference with respect to the demographic information of the study area. For the calculations of the report, the waste generation will be evaluated from all individuals as a whole. Waste streams are not purely based on their respective areas/ personnel which results in minor inaccuracies. The margin of error is expected to be a maximum of 8% in the worst-case scenario. At a 95% confidence level, an acceptable margin of error utilized by most studies often ranges between 4% to 8%.

Data analysis

The waste generated on the theoretical campus was categorized into five classifications as follows:

1. Paper and cardboard waste (Wastepaper),

2. Plastics and metals waste,

3. Bio waste.

4. Glass waste,

5. Mixed waste

Although recycling practices and businesses are quite advanced in the United Arab Emirates, most of the institutions use traditional waste collection services. This is a result of the public unawareness of the importance and benefits of transforming their waste streams in a circular economy scheme. Regarding the technologies and capabilities, most of the waste streams mentioned show an existing recycling market in Al Ain except for food packaging waste and sanitary waste which is classified as non-recyclable waste.

RESULTS AND DISCUSSION

Calculations for the waste generated in the university's campus will be based on the year 2019 as it presents the latest publications from the U.A.E.'s governmental authorities regarding waste generation.

Waste generated by University-X and its categorization

The total waste generated by the university in tons per annum according to the assumptions made is calculated below:

Waste generated=290.3 Kg × 10,700

Individuals=3106210 Kg=3106.2 tons

According to the study made, the annual categorization and loads of waste from the five different waste collection areas with respect to the demographic information of the study area were as follows (Table 1).

Table 1: Annual percentages and waste loads from the defined areas.

	Dormitories buildings	Food courts	Playgrounds and roads	Academic areas	Laboratories building
Percentages	36%	44%	7%	5%	8%
Waste load	1118.2 tons	1366.8 tons	217.4 tons	155.3 tons	248.5 tons

As a common year consists of 52 weeks and 260 workdays, the total waste generated by the university is calculated to be approximately 12 tons daily. The categorization of waste depending on the kinds of waste streams with respect to the demographic information of the study area was as follows (Table 2).

Table 2: Categorization and loads of waste.

	Wastepaper	Plastics and metal waste	Bio waste	Glass waste	Mixed waste
Percentages	12%	13%	64%	1%	10%
Waste load	1.4 tons	1.6 tons	7.7 tons	0.1 tons	1.2 tons

Waste management

Current waste management system (Scenario 1): As aforementioned, the waste management technique assumed to be followed in University-X is based on the Municipal Waste Management system in the Emirate of Abu Dhabi and the efficiency statistics are from the official report published by the 'Statistics Centre of Abu Dhabi (SCAD)' in 2019 [4]. According to the statistics; of the total municipal solid waste; 58.58% is managed by recycling, 02.26% is managed by composting, 18.33% is transported to landfills, and 20.83% is either transported to dumpsites or to waste management firms. The last two resemble the main problem in the country, where they total 39.16% representing unsustainable management techniques. With respect to University-X, this percentage is equal to 1216.4 tons of its waste generation not being treated in a sustainable way which is where the zero-waste approach comes in handy.

Zero-waste approach (Scenario 2)

Zero-waste index: The Zero-waste index is a cutting-edge technique for measuring waste management systems' substitution of virgin materials. The potential for virgin material offsets and natural resource depletion could be quantified by establishing the zero-waste index internationally. The Z.W.I. also provides a more comprehensive view of a city's prospective need for raw materials, energy, carbon emissions, and water. As a result, the Z.W.I. is a performance indicator used to evaluate the overall performance of waste management systems and it is calculated as follows [5]:

$$ZWI = \frac{\sum_1^n WMSi.SFi}{\sum_1^n GWS}$$

Where:

WMSi – is the amount of waste managed by the system (n=amount of waste avoided, recycled, treated, etc.),

SFi – is the substitution factor for different waste management systems based on their virgin material replacement efficiency, and

G.W.S. – is the total amount of waste generated (tons of all waste streams).

The Z is determined by the value of the material that potentially replaces the virgin material inputs. Material substitutions take into account the substitution of energy, water, and greenhouse gas emissions. Substitution values for material, energy, water, and Greenhouse Gas (GHG) emissions were derived from the life cycle databases of several life cycle assessment tools and information sources. The amount of materials and resources substituted is positively connected to technological advancements employed in the material recovery process; hence, the substitution value differs for different materials and waste management systems [6].

For this study, the zero-waste management system was assumed to be running ideally with maximum efficiency. Following this, the maximum substitution values were taken for the system which resulted in a daily substitution of virgin materials amounting to 8.59 tons, energy substitution of 137.89 MJ/ton, Greenhouses Gases (GHG) emissions reduction of 14.76 CO2e/ton, and water savings of 2.11 L. The zero-waste index was calculated to be 0.72 compared to 0.61 before applying the zero-waste approach. The Z.W.I. difference is not significant due to the high generation of bio waste which troubles material recovery.

Zero-waste application: Before applying the Zero-waste approach, some arrangements should be satisfied. One is signing a contract with an external entity that provides more advanced waste management techniques. One of these is 'Averda', which is a firm offering sustainable solutions that extract value from waste while decreasing the use of the planet's scarce natural resources and promoting the circular economy [7]. The company operates in India, the Middle East, and Africa. Regarding University-X, it has been assumed that Averda carries out the whole process of cleaning, waste collection, and waste treatment. The second arrangement that should be met is the creation of sorted waste streams by providing sorting waste bins. The required number of waste bins was calculated using the equation following [8]:

$$N = (S_f \times W_{tot}) / (\pi \times W_{wb})$$

Where:

N – is the essential number of waste bins for the selected collection point,

S_f – the safety factor, usually estimated at 10% → S_f=1.1 to prevent waste spilling,

W_{tot} – the total amount of waste generated per week [Kg],

W_{wb} – the mass of waste in a full waste bin [Kg], and

π – the collection frequency per week

Using this equation, the essential number of waste binds needed to perform sorted waste collection can be identified and the numeral depends on the different sizes provided by the recycling company and their collection frequency. The five streams of waste defined earlier in the study will be collected separately. The collection is assumed to be inside and outside of the campus, as the inner bins will be daily emptied for the hygiene of the building [9]. Those waste bins were chosen to be of 60 Kg capacities. Equation 2 parameters will change to evaluate the needed per day rather than per week.

Calculations recorded that 26 wastepaper bins, 30 plastics and metals waste bins, 142 bio waste bins, 2 Glass waste bins, and 22 mixed waste bins are essential to perform separate waste collection at the source to create a pure waste stream for better application of treatment techniques. Waste bins should be distributed with respect to the activities in the intended location; where more bio waste bins should be placed in the food court and so forth.

The external collection waste bins have been chosen to be of 1100 Kg capacities with a width of 1375 mm, a depth of 1470 mm, and a height of 1075 mm. Capacities of waste bins are not ideal for calculations because different sizes and volumes of waste also play a critical role in the required collection frequency [10]. Following this, those containers will be assumed to have an average of 250 Kg for the densities of the different waste streams. The equation used to calculate the needed 250 Kg containers is as follows:

Required containers=Waste quantity (Kg)/Average density of container

Calculations recorded that 6 wastepaper containers, 7 plastics and metals waste containers, 31 bio waste containers, 1 glass waste container, and 5 mixed waste containers are essential to perform separate waste collection at source. The distribution of containers will be distributed similarly to the previous with the respect to the activity in the location. The costs of the prearrangements totals the cost of 222 60-Kg waste bins and 50-1000 Kg containers, where the first costs about 370 Dirhams while the other costs about 2100 Dirhams. The total was calculated to be 187,140 Dirhams. The other arrangement regarding the collection frequency was assumed with Averda and will comprise the collection of wastepaper three times per month, glass waste once per month, plastics and metals once per week, bio waste daily, and mixed daily [11].

Averda also developed small recycling centers that can be installed at different locations around the university's campus. These recycling centers are equipped with smart recycling bins that send the company signals indicating that it is full, which helps in minimizing emissions from unneeded transportation trips. The recycling centers are powered by renewable energy from the installed solar panels [12].

After the waste has been collected-it is transported to Averda's facilities which provide the following services: Material Recovery Facilities (MRF) and recycling centers, composting, Refuse Derived Fuel (RDF), power generation, incineration, and thermal desorption.

Those services can assure that the campus can achieve the zero-waste initiative and the chosen services depend on the waste type, their costs, and the economic benefit of the product. For example, food and organic waste can be composted, producing nutrient-rich material for the greenery landscapes on the campus. In addition, engineering field experiments that create sand, rock, and concrete, may be processed and treated by specific technology into smaller particles that can be reused for various applications, such as aggregate for roadwork. The non-recyclable and non-compostable materials that remain after all of the treatment processes are completed, on the other hand, would be incinerated in environmentally sensitive facilities, resulting in the generation of particles and carbon that would be captured, and the resulting ash could be used to make bricks [13].

Another important advantage of the chosen recycling firm is that it also provides web-based reports which allow for data regarding all aspects of the projects to be monitored and assures that the firm and the universities are moving in the right direction to satisfy the intended goal. Averda's web-based reports are based on Key Performance Indicators (KPIs), which are key performance indicators that show how far you've come toward your goal. They serve as a focal point for strategic and operational improvement, providing an analytical foundation for decision-making and assisting in focusing attention on the most important issues [14].

SWOT analysis

This section of the report will detail a SWOT analysis of the waste management system of Al Ain region compared to the anticipated zero-waste management system. The comparison is detailed in the table below (Table 3).

Table 3: SWOT analysis of waste management systems.

	Waste management system of Al Ain region	**Zero-waste management system**
Strengths	Local authorities designed recycling systems for various types of domestic solid wastes.	Available expertise in the field of recycling and zero waste in the country.
	Studies are constantly conducted to reduce the amount of rejected items sent to landfill.	Financials required to apply the initiative are available.
Weaknesses	The city's economic development	Unawareness of public about the
	It was based on high consumption resulting in high waste generation.	Severity of the problem of waste generation in the country.
	The city's environmental capabilities will not be able to support it if this economic model continues.	Separate collection at the source and creating a pure waste stream is almost impossible.
Opportunities	The government is focusing	A circular economy puts products
	Research on circular economy which includes ecological modernization, green growth, and low-carbon development.	Back into the market which yields financial benefits.
		University will allocate more funds toward research and other important fields
Threats	Significant annual population	People's compliance with the
	It increases resulting in a significant increase in waste generation.	Initiative and its requirements.
	High tourism rates result in high consumption rates and thus higher	Markets of recycled products are not familiar or publicized in the region.
	Waste generation rates.	

CONCLUSION

The U.A.E. is facing a significant problem with its waste generation specifically with plastic waste. The county is now introducing new laws preventing the use of un-biodegradable plastics and issuing tariffs on their use if deemed necessary. Following that, it has been recorded that a significant decrease in un-biodegradable plastic uses at both corporate levels and individuals' personal use. Strict prevention or reduction at the source of specific products could be a major solution to the problem and one that will help decrease the waste generation in the country significantly.

Regarding the zero-waste approach suggested in this study, it has been found that the initiative has been applied before in the U.A.E. by MARS Inc. and Masdar city, both representing huge corporations effectively circulating all their waste back into use. Those corporations first raised awareness of the problem of waste generation in the country to encourage their employees to participate aiming to achieve perfect models, then they performed separate collection at source in their locations, and signed contracts with waste management entities in the country that have expertise in circulating specific streams of waste back into use, similar to Averda which was chosen to apply the zero-waste approach in University-X.

Of the limitations faced in the study, confidentiality purposes led to the study being based on demographic data and similarities but not on actual data from a university building located in Al Ain region. Although the model created was realistic based on the data, it doesn't strictly describe the case in the study area. Another is that the majority of waste treatment services depend on the financials available and the intended products after treatment so a budget should be set for waste management by University-X before deciding on the services.

This study presents findings about the feasibility of adopting a zero-waste approach on a university campus located in Al Ain Region of the city of Abu Dhabi in the United Arab Emirates and how the transformation could be achieved.

AUTHOR CONTRIBUTIONS

Conceptualization, M.E.A. and P.M.; methodology, M.E.A. and

P.M.; software, M.E.A.; validation, M.E.A. and P.M.; formal analysis, M.E.A.; investigation, M.E.A.; resources, M.E.A.; data curation, M.E.A.; writing—original draft preparation, M.E.A.; writing— review and editing, M.E.A. and P.M.; visualization, M.E.A.; supervision, P.M.; project administration, P.M.; funding acquisition, P.M. All authors have read and agreed to the published version of the manuscript.

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DATA AVAILABILITY STATEMENT

The data used in the manuscript are downloaded from public access and are open source data. Load data downloaded from https://www.scad.gov.ae/(accessed on 7 October 2022). Data from http://doi.org/10.3390/su12083086 (accessed on 7 October 2022).

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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