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Environmental impact assessment of solid waste disposal options in touristic islands

Ali Daryabeigi Zand*, Azar Vaezi Heir

School of Environment, College of Engineering, University of Tehran, Tehran, Iran

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ABSTRACT

Kish Island is a popular tourist destination in Iran, and tourism plays an important role in its economy. The volume of waste produced in the island has increased given the construction of numerous industrial projects over the past decade, as well as an increase in the tourist population. This expansion signals a need to create new methods of waste disposal. Environmental Impact Assessment (EIA) is a process that can be used to evaluate the impact of waste disposal options on Kish Island. Rapid impact assessment matrix (RIAM) is a powerful tool to carry out the environmental impact assessment. The RIAM conducted in this research incorporated the mathematical sustainability model to evaluate the impacts of four municipal solid waste disposal options on the environment on Kish Island. The options included: (Option 1) Continuing the current disposal activities in Kish Island, i.e., 50% waste recycling and 50% waste landfilling; (Option 2) 30% composting, 50% waste recycling, and 20% waste landfilling; (Option 3) 30% composting, 50% waste recycling, and 20% waste incineration; and (Option 4) 50% waste recycling and 50% waste incineration. Among these options, option 4 was the priority for the establishment of final waste disposal with the highest score (0.043) in terms of sustainability, as well as having fewer adverse environmental impacts. However, the current environmental status of the Kish Island disposal site (Option 1) had the lowest score (-0.263) in terms of sustainability and was found to be the last priority with the most destructive environmental effects.

1. Introduction

Due to economic development and urbanization, municipal solid waste (MSW) production has increased rapidly, and its composition has dramatically changed. Such changes have placed greater pressure on the environment, human health, and municipal solid waste management (MSWM) [1,2]. Solid waste management (SWM) is a dilemma for many islands throughout the world. Since many islands are tourist destinations, waste production is relatively high [3]. Waste management is also a common challenge in numerous cities in developing countries. The increase of MSW production as a result of population growth in most urban areas has led to difficulties in finding appropriate lands for final disposal [4-6]. Landfills that do not comply with the set standards can have a negative impact on the environment [7]. As modern landfills under new standards and regulations have been constructed with high maintenance costs, the appropriate facility is set up in a vast area capable of handling a large amount of waste in a region. Public opposition to waste disposal sites in proximity to populated areas, as well as a variety of financial, political, and geographical factors, emphasize the need to construct waste disposal sites in remote regions [8].MSW conditions can affect the climate, human health, and other organisms. Air pollution and the contamination of soil, groundwater, and surface water are favorable to the proliferation of insects and vermin in non-sanitary waste sites, which leads to serious health problems [9,10]. The pollution of water resources is caused by leachate from wastes containing harmful chemical elements, bacteria, parasites, and other microorganisms that can physically change the color and properties of the water [11-13]. Soil pollution is also caused by toxic

*Corresponding author.
E-mail address: adzand@ut.ac.ir
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compounds such as cadmium, chromium, lead, and mercury released from unsafe and improperly managed MSW disposal sites [14,15]. Several resources are available to anticipate and reduce the effect of proposed activities. Among these methods are environmental risk mapping, life cycle analysis, environmental impact assessment, multi-agent system, linear programming, and agro-environmental indicators [16]. EIA is one of the most successful approaches to evaluate and predict the environmental effects of a project including the physical, chemical, biological, ecological, socio-cultural and economical impacts [17]. The components of the EIA process include scoping, checklists, matrices, qualitative and quantitative modeling, literature reviews, and decision-making systems [18,19].Christopher Pastakia presented the Rapid Impact Assessment Matrix for the first time in 1998 [20]. RIAM can be used as a powerful tool to carry out environmental impact assessment on projects due to its simple structure, high capability in deep and iterative analysis, high accuracy, flexibility, and the ability to perform an objective evaluation [21]. It should be noted that matrix methods only introduce the direct effects, and their disadvantages such as timing or duration of impact are not mentioned. In a study, upgrading of the available site, developing a biogas plant, and constructing a new sanitary site in Jordan were suggested after the environmental impact assessment [22]. RIAM was the most suitable means to evaluate the choices available to address the waste disposal issue for the city of Varanasi, India, in 2010; a sanitary landfill was found to be the best option [23].It is critical to recognize that landfill operations can cause noise pollution and also contaminate the soil with toxic leachate. The weakness of many interpretations of sustainable development is that it is considered to be inadequate for environmental management and protection. As a result, many evaluations focus on environmental protection and are less likely to address socioeconomic issues [24]. However, the interpretation of sustainable development is still based on subjective assessment. In this regard, Philips (2009) developed a mathematical model for defining the principles of sustainability and its possible application in quantitative EIAs to determine the level and nature of sustainable development of projects and operations [25-28]. The aim of this research was to use RIAM analysis to incorporate a mathematical sustainability model to determine the impact of the landfill on the environment in Kish Island. Various plausible options were evaluated with respect to their environmental impacts to select the best practical option to improve the quality of the landfill.

2. Methodology

2.1. Description of the solid waste transfer station (SWTS) in Kish Island; Iran

Kish Island with an area of 91.5 km^2 is located in Bandar Length District, Hormozgan Province. Coral reefs and several other small islands are found along the Coast of Kish Island. The island with the population of approximately 40000 has several shopping centers, tourist attractions and hotels and known to be a free trade zone in Iran. Annually around one million tourists visit the Kish Island. Kish has a semi-equatorial arid climate with the mean annual precipitation of 145 mm (54% in winter, 28% in fall, and 14% in summer) and annual average temperature of 26.6°C. For most of the year, the humidity is about 60%. The weather is mild between October and April (18-25°C) in Kish Island [29,30]. The landfill of the Kish Island is located southeast of the island, with an area of 9500 square meters. Figure 1 shows the location of Kish Island as well as its waste disposal site. According to the statistics, the per capita waste generated daily in Kish Island is 2.38 kg. Table 1 presents the physical composition of the MSW in Kish Island.

According to the Kish Civil, Water, and Urban Services Company, in addition to municipal solid waste, a total of 1,343 tons of green space waste and material, 1,199 tons of municipal bulk waste, and 6 tons of hospital waste was recovered in Kish. About 50% of the collected waste is recycled, and the rest is buried. Due to the absence of a proper collection method, leachate flows into the landfill area, where it penetrates the soil and has the potential to contaminate the groundwater. The chemicals in the leachate can adversely affect the soil quality, if they are not managed properly. Therefore, the soil chemistry changes and leads to a reduction in growth and even the destruction of plants. The dust from semi-trailers transferring waste to the site results in air pollution that can affect the breathing of workers and residents; the release of unpleasant odors from waste products also causes air pollution. Noise pollution is another source of environmental damage from the landfill, which is caused by various sources, including motor vehicles. Failure to create a suitable barrier around the disposal site, the lack of proper containment, and the presence of the above mentioned contaminants have affected the landscape.

Table1. Physical composition of MSW in Kish Island, Iran in 2018.

	Food and vegetable	Paper products	Plastic	metal	Rubber	Textile	glass	wood	others
Kish Island (%)	34.85	20.13	22.15	4.31	0.31	4.57	2.86	1	9.82
Iran (%)	72.04	6.43	7.77	2.52	1.14	2.86	2.03	1.10	4.11

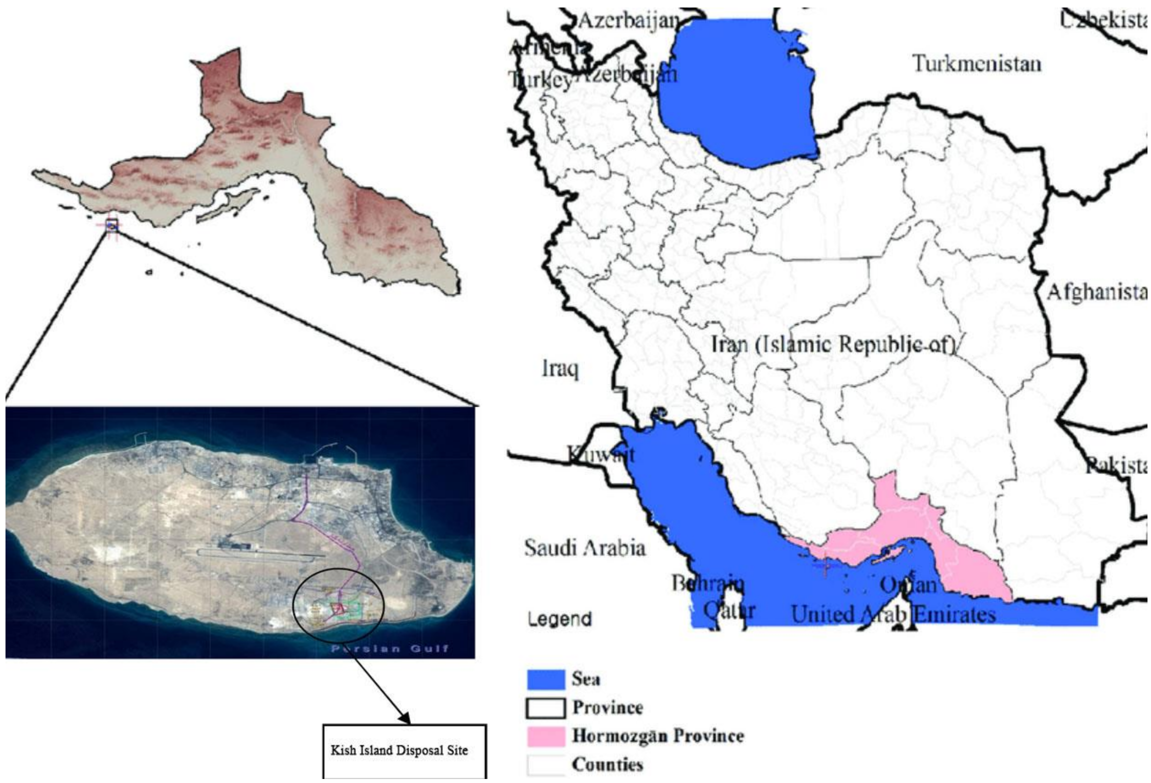

Fig.1. The study area in Kish Island, Iran.

2.2. RIAM analysis

The RIAM method defines the assessment criteria and specifies the data collection procedure for these criteria. This method correspondingly describes the conditions for each criterion and assigns an independent score to each of the conditions. The score values assigned to different conditions have been well described in the literature [21,23]. The impacts of the project activities on environmental components are assessed by the individual score of each component. The score of an environmental component serves as a measure of the expected impact on that component. In the RIAM method, the environmental components are categorized as physical/chemical (PC), biological/ecological (BE), sociological/cultural (SC), and economical/operational (EO). The criteria are categorized into two categories: (A) criteria that are significant to the condition and affect the final score independently and (B) criteria that represent the significance of the situation and do not affect the final score independently [21]. The score attributed to each category of the criteria is determined using Equations 1-3. For the set of criteria in group (A), multiplication of the assigned scores is calculated in the scoring system, while the sum of the assigned scores is calculated for the set of criteria in group (B). The reason for defining such a scoring system is that the multiplication ensures taking cognizance of the weight of each score value in group (A), while the addition ensures preventing individual score values to influence the overall score, yet accounts for the cumulative significance of the score values in group (B). Finally, the sum of the score values in group (B) is multiplied by the product of the score values in group (A). The result represents the final assessment score (ES) for the condition. The operations for the RIAM in its present form are as:

$$(A1)\times(A2)=AT \quad (1)$$

$$(B1)+(B2)+(B3)=BT \quad (2)$$

$$(AT)\times(BT)=ES \quad (3)$$

(A1) and (A2) are the individual scores for the criteria in group (A). Similarly, (B1), (B2), and (B3) are the individual scores for the criteria in group (B). AT is the product of all score values for (A), and BT is the sum of all score values for (B). ES is the environmental score for the corresponding condition [21,23].

2.2.1. Environmental components

The environmental components in RIAM fall under four categories:

1. Physical/chemical (PC): Involve all physical and chemical aspects of the environment.
2. Biological/ecological (BE): Involve all biological aspects of the environment.
3. Sociological/cultural (SC): Involve all human aspects including the cultural aspects of that particular area of the project.

4. Economical/operational (EO): involve identifying the economic consequences of environmental change, both temporary and permanent.

After the environmental components are formed, scoring takes place and eventually, the environmental score (ES), which represents the environmental status of the project activities, is calculated from the formulae given in Eqs. 1-3. After the ES is calculated, in order to provide a more accurate system of measurement, ES points that are in the range (RB = Range Bond) can be computed (Table 2).

When the environmental score (ES) is set into a range band, it can be individually shown or represented in graphical and numerical form according to the type of component [22]. A field investigation was conducted to gain better insight into the reloaded condition of SWTS. The investigation of the different options for the Kish Island disposal site has primarily focused on the prevention of environmental destruction and improving the quality of life of the local people. The four potential options are comprised of the current condition and three alternative options:

Option 1: Continuing the current disposal activities, i.e., 50% waste recycling and 50% waste landfilling

Option 2: 30% composting, 50% waste recycling, and 20% waste landfilling

Option 3: 30% composting, 50% waste recycling and 20% waste incineration

Option 4: 50% waste recycling and 50% waste incineration

Option1 includes open dumping, which is the current method practiced at the Kish disposal site. This method involves 50% of solid wastes recycled and the rest of them being dumped into the ground and covered. The other three proposed options would upgrade the existing landfill by using a combination of different methods consists of composting, dumping, recycling, and incineration. Recycling would require enhanced facilities for the current recycling processes. Besides, approximately 35% of the solid wastes produced in Kish Island are appropriate for composting.

Table 2. Conversion of environmental scores to range bands [21].

RB Description	RB	ES
Major positive change/impacts	+E	+72 to +108
Significant positive change/impacts	+D	+36 to +71
Moderately positive change/impacts	+C	+19 to +35
Positive change/impacts	+B	+10 to +18
Slightly positive change/impacts.	+A	+1 to +9
No change/status quo/not applicable	N	0
Slightly negative change/impacts.	-A	-1 to -9
Negative change/impacts	-B	-10 to -18
Moderately negative change/impacts	-C	-19 to -35
Significant negative change/impacts	-D	-36 to -71
Major negative change/impact	-E	-72 to -108

The materials would be transported to a fermentation site. At this site, the wastes would be converted into compost through aerobic fermentation, while the dry materials are separated by optimized methods and returned to the production cycle. Composting has economic and environmental benefits, including eliminating pathogens and weeds, reducing the volume of wastes, and producing fertilizer [31]. The best approach for waste management is incineration with energy recovery. While incineration produces some amount of waste, it is reduced to only 10% of the original waste. In order to evaluate the environmental impact assessment, a list of daily activities at the Kish Island disposal site was prepared, and the environmental components were developed by these activities. The associated activities and their impact on the environmental components were determined. The data from this step were used to score in the RIAM matrix. A questionnaire was prepared using all the components mentioned for each option. This questionnaire was then answered by people who lived near the stations and by a group of experts in the field. The results based on the questionnaires are shown in Table 3 for Option 1.

2.3. Sustainability

A model developed by Phillips [25-28,32-34] was applied to evaluate the different options proposed for SWTS, and whether they could be considered as sustainable or unsustainable. Also, if it is sustainable, what is the level and nature of sustainability for the option(s) of SWTS in the study area? The Philips mathematical model of sustainability is used to define the principals of sustainable development. Also, the feasibility of applying the Philips model in EIAs to determine the levels of sustainability of projects and operations are presented. The Philips mathematical model is expressed as:

$$\text{S-value}=\text{E}-\text{H}_{\text{N}} \tag{1}$$

Where, S represents sustainability; E represents the environmental components such as physical, chemical, biological, and ecological components; and H_{NI} represents human requirements and resources, including sociological, cultural, economic, and operational. E, and H_{NI} are obtained using Equations 2-3, and Equation 1 yields the level and nature of sustainability.

$$\text{E\_value} = \frac{\sum \text{PC} + \sum \text{BE}}{\text{PCmax} + \text{BEmax}} \tag{2}$$

$$\text{H}_{\text{NI}}\text{\_value} = \frac{(\text{SCmax}-\Sigma\text{SC})+(\text{EOmax}-\Sigma\text{EO})}{(\text{SCmax}+\text{EOmax})} \tag{3}$$

According to Equations 4-5, a plan is sustainable if the obtained values for E are greater than those for H_{NI}, and unsustainable otherwise.

$$\text{E-value} \geq \text{HNI-value} \Leftrightarrow \text{S} > 0 \tag{4}$$

$$\text{E-value} \leq \text{HNI-value} \Leftrightarrow \text{S} \leq 0 \tag{5}$$

By determining whether a plan is sustainable or unsustainable, the level and nature of sustainability can also be determined according to the score values assigned to conditions that are presented in reference [32].

Table 3. RIAM Analysis Matrix (Option1: Continuing the current disposal activities in Kish Island, i.e., 50% waste recycling and 50% waste landfilling).

components	A1	A2	B1	B2	B3	RB	ES
1.Physical/chemical components							
PC 1 Dust emission	2	-2	2	2	3	-C	-28
PC 2 Volatile organic compound emission and other toxic gases	1	-2	2	2	3	-B	-14
PC 3 Noise pollution from activities atdisposal site	1	-2	2	2	2	-B	-14
PC 4 The solid waste disposal	2	-3	2	2	3	-D	-54
PC 5 Leaching from the existing municipal solid waste dump sites	2	-2	3	3	3	-D	-36
PC 6 Leachate and groundwater contamination	3	-3	2	2	3	-E	-82
PC 7 Odor emission	1	-2	2	2	2	-B	-12
2.Biological/ecological components							
BE 1 Decreased marine turtle habitat security	4	-3	3	3	3	-E	-108
BE 2 Leachate effect on groundwater	3	-3	3	3	3	-E	-81
BE 3 Leachate effect on surface water	3	-3	3	3	3	-E	-81
BE 4 Leachate effect on soil, health and quality	2	-3	3	3	3	-D	-54
BE 5 Pollution effect on the aquatic ecosystem	2	-3	3	3	3	-D	-54
BE6 Destructive effects on animals and plant habitats	2	-2	3	3	3	-D	-36
BE 7 Production and diffusion of pathogens	2	-2	3	2	3	-C	-32
BE 8 Effects of decomposition of wastes	1	-3	3	3	3	-C	-27
BE 9 Effect of air and water pollution on green spaces	2	-1	3	3	3	-B	-18
3.Sociological/cultural components							
SC 1 Effect on quality of life of people that settled near stations	1	-2	3	2	3	-B	-16
SC 2 Effect of dust and odor on local people	1	-2	3	2	3	-B	-16
SC 3 Effect on sense of belonging on local people	1	-1	3	2	3	-A	-8
SC 4 Problems people face due to noise pollution.	1	-2	3	2	3	-B	-16
SC 5 Effect of volatile organic compounds on local people	2	-2	3	2	3	-C	-32
SC 6 Work opportunity	2	1	2	2	2	+B	+12
SC 7 Effect on Tourism	3	-3	3	3	3	-E	-81
4.Economical/operational components							
EO 1 Operating and running costs of incineration plants	2	1	2	2	1	N	0
EO 2 Cost for waste transferring and manpower	1	0	3	1	1	N	0
EO 3 Costs involved in recycling and reuse of municipal solid wastes.	2	-1	2	2	2	-B	-12
EO 4 Economical benefits from reuse/recycling wastes	1	2	2	2	2	+B	+12
EO 5 Costs for the collection of leachate.	2	0	2	2	2	N	0
EO 6 Revenues of composting	2	0	3	2	2	N	0
EO 7 Costs for the composting	2	0	3	2	2	N	0

Seven physical/chemical components (PC), nine biological/ecological components (BE), seven social/cultural components (SC), and seven economical/operational components (EO) have been considered:

1. Physical/chemical components
   - PC 1 Dust emission.
   - PC 2 Volatile organic compounds emission and other toxic gases.
   - PC 3 Noise pollution from trucks and other activities at the disposal site.
   - PC 4 The solid waste disposal.
   - PC 5 Leaching from the existing municipal solid waste dump sites.
   - PC 6 Leachate and groundwater contamination.
   - PC 7 Odor emission.
2. Biological/ecological components
   - BE 1 Effect of pollution on bird migration from landfill area.
   - BE 2 Leachate effect on groundwater.
   - BE 3 Leachate effect on surface water.
   - BE 4 Leachate Effect on soil, health, and quality.
   - BE 5 Pollution Effect on the aquatic ecosystem.
   - BE6 Destructive effects on animals and plant habitats
   - BE 7 Production and diffusion of pathogens.
   - BE 8 Effects of decomposition of wastes.
   - BE 9 Effect of air and water pollution on green spaces.
3. Sociological/cultural components
   - SC 1 Effect on quality of life of people that settled near stations.
   - SC 2 Effect of dust and odor on local people.
   - SC 3 Effect on sense of belonging on local people.
   - SC 4 Problems people face due to noise pollution.

- SC 5 Effect of volatile organic compounds on local people.
- SC 6 Work opportunity
- SC 7 Effect on Tourism

4. Economical/operational components

- EO 1 Operating and running costs of incineration plants.
- EO 2 Cost for waste transferring and manpower.
- EO 3 Costs involved in recycling and reuse of municipal solid wastes.
- EO 4 Economical benefits from reuse/recycling of wastes.
- EO 5 Costs for the collection of leachate.
- EO 6 Revenues of composting
- EO 7 Costs for the composting

3. Results and discussion

3.1. RIAM evaluation

Primarily, the assessment results of the landfill in Kish Island were obtained using the RIAM method as indicated in Table 4. The negative impacts of the environmental components, human requirements, and resources are expressed in negative numbers. When absolute values for H_{NI} are greater than E values, it is suggested to change the ES domain by adding the constant value of 108 to the obtained values for ES. Hence, the ES values will fall between 0 and 216 as presented in Table 5.

Table 4. Summary scores of RIAM analysis matrix for all potential options.

Option 1:50% waste recycling and 50% waste landfilling										
class	-E	-D	-C	-B	-A	N	A	B	C	D	E
PC	1	2	1	3	0	0	0	0	0	0	0
BE	3	3	2	1	0	0	0	0	0	0	0
SC	1	0	1	3	1	0	0	1	0	0	0
EO	0	0	0	1	0	5	0	1	0	0	0
Total	5	5	4	8	1	5	0	2	0	0	0
Option 2: 30% composting, 50% waste recycling and 20% waste landfilling											
PC	0	0	1	4	2	0	0	0	0	0	0
BE	0	3	2	2	1	0	0	0	1	0	0
SC	0	0	0	5	1	0	0	0	1	0	0
EO	0	0	0	2	0	2	0	1	2	0	1
Total	0	3	3	13	4	2	0	1	4	0	1
PC	0	0	0	1	5	1	0	0	0	0	0
BE	0	0	0	2	5	1	0	0	0	1	0
SC	0	0	0	0	1	5	0	0	1	0	0
EO	0	0	0	1	1	2	0	2	0	1	0
Total	0	0	0	4	12	9	0	2	1	2	0
Option 4:50% waste recycling and 50% waste incineration											
PC	0	0	0	1	0	6	0	0	0	0	0
BE	0	0	0	1	1	7	0	0	0	0	0
SC	0	0	0	1	0	5	0	0	1	0	0
EO	0	0	0	2	0	3	0	1	0	1	0
Total	0	0	0	5	1	21	0	1	1	0	0

The analysis of different options indicates the difference between the options for positive effects and the negative impacts of the landfill on different components of the project. The ES scores of the individual matrix of the RIAM analysis are presented in Table 4. The analysis of different options indicates the difference between the options for positive effects and the negative impacts of the landfill on different components of the project. The ES scores of the individual matrix of the RIAM analysis are presented in Table 4. A summary of the ES scores of all the environmental components is illustrated in Figure 2.

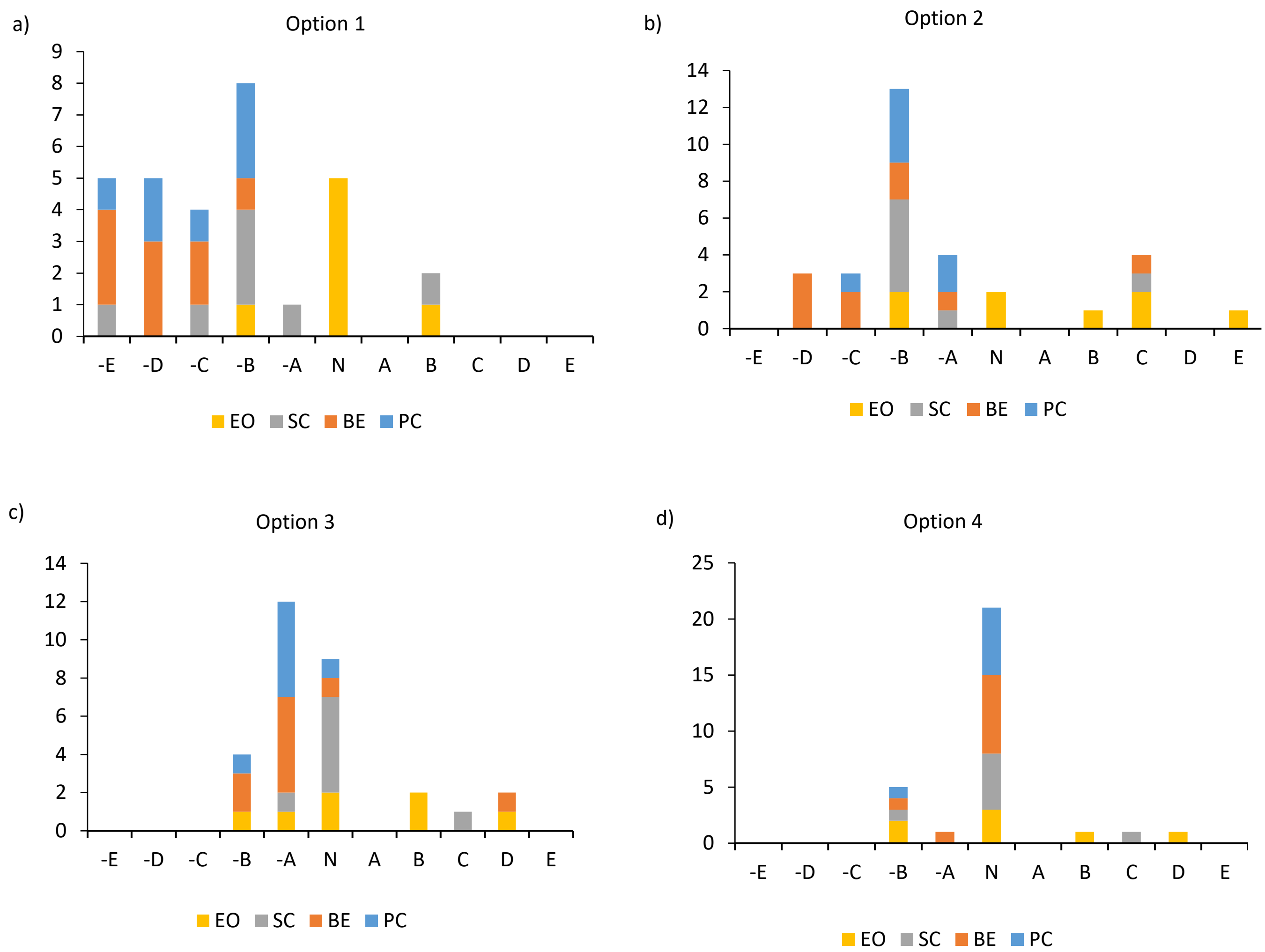

Fig. 2. RIAM analysis for the evaluated options. PC: Physical/chemical components; BE: Biological/ ecological components; SC: Sociological/cultural components; EO: Economical/operational components.

3.1.1. Option 1: The current condition of Kish landfill (50% recycling and 50% landfilling)

The majority of the impacts evaluated in Option 1 were negative. Only two items were evaluated as having positive impacts. The most significant overall impacts were in the Biological/ecological (BE) category due to the severe negative impacts on biota and the local ecological system.

The most significant negative impact of the BE components is related to the decrease in the safety of marine turtle habitat. The sandy beaches of Kish Island have long been home to hawksbill sea turtle nesting, despite urban development and the increasing stress and pollution created in recent years. However, turtles still come to Kish Island for feeding and breeding. The hawksbill is scattered all over the island of Kish, mainly on the northwest and southwestern coasts. The hawksbill sea turtles found in the west and north feed on algae and sponges. Hawksbill turtles are endangered species (CR species is one listed as a sea turtle of the Cheloniidae family by the International Union for Conservation of Nature). It is the only remaining Eretmochelys species in the genus. Besides the contamination of the local soil due to leachate infiltration, waste such as plastics can also cause the turtles to choke. The Sociological/cultural components were also evaluated as negative points due to their effects on the health of the local people and the public safety of those living in the vicinity of the landfill. As a result, the current landfill is a significant deterrent for people wanting to live in the area. The only positive aspect of this option is associated with work opportunities.

3.1.2. Option 2:30% production of compost from the organic components, 20% landfilling other wastes, and 50% recycling

Option 2 had less negative impacts than Option 1 (Table 4 and Figure 2) as concerning destructive effects on the aquatic ecosystem and other animals as well as the local community. The main focus was on reducing the effect of the negative impact of the PC and BE components. The production of compost from wastes, and the reduction of by-products such as methane from waste decomposition, should contribute to reducing anthropogenic sources of climate change and improve the health of the residents around the complex.

Table 5. The relative ES for the project options, based on original ES totals used in Table 6.

	Option 1		Option 2		Option 3		Option 4	
	Original	Relative ES	Original	Relative ES	Originals	Relative ES	Originals	Relative ES
PC1	-28	80	-18	90	-8	100	0	108
PC2	-14	94	-9	99	-8	100	0	108
PC3	-14	94	-14	94	-14	94	-14	94
PC4	-54	54	-18	90	-8	100	0	108
PC5	-36	72	-18	90	-8	100	0	108
PC6	-82	26	-32	76	0	108	0	108
PC7	-12	96	-8	100	-6	102	0	108
BE1	-108	0	-18	90	-6	102	0	108
BE2	-81	27	-24	84	-8	100	0	108
BE3	-81	27	-24	84	-8	100	0	108
BE4	-54	54	-36	72	-10	98	0	108
BE5	-54	54	-36	72	-6	102	-8	100
BE6	-36	72	-36	72	-12	96	-12	96
BE7	-32	76	-18	90	0	108	0	108
BE8	-27	81	36	144	36	144	0	108
BE9	-18	90	-8	100	-6	102	0	108
SC1	-16	92	-10	98	0	108	0	108
SC2	-16	92	-10	98	0	108	0	108
SC3	-8	100	-8	100	0	108	0	108
SC4	-16	92	-16	92	0	108	0	108
SC5	-32	76	-16	92	-6	102	-10	98
SC6	12	120	24	132	24	132	28	136
SC7	-81	27	-14	94	0	108	0	108
EO1	0	108	0	108	0	108	-14	94
EO2	0	108	0	108	0	108	0	108
EO3	-12	96	-12	96	-12	96	-12	96
EO4	12	120	12	120	12	120	12	120
EO5	0	108	21	129	36	144	54	162
EO6	0	108	24	132	18	126	0	108
EO7	0	108	-12	93	-8	100	0	108

3.1.3. Option 3:30% waste incineration with 30% production of compost and 50% recycling.

The majority of components in Option 3 were classified as indicating no change, and the only difference with the second option was the absence of buried wastes. This option consists of 30% incineration from the rejected waste of composting and recycling. It can diminish the destructive effect of leachate infiltration in soil and dust emissions. Obviously, this option has less deleterious environmental effects than Options 1 and 2. It has a positive effect on the EO and SC components because of the compost benefit and reduced leachate collection cost due to low leachate production.

3.1.4. Option 4: 50% waste incineration with 50% recycling

Option 4has the highest utility among the available options. The priority was given to the landfill. The common adverse effects associated with this option were related to dust and gas emissions and have destructive effects on ecosystems and habitats. The most considerable impact of incineration, which any design and management plan must notice, is the emission of atmospheric emissions of particulate matter, CO_2, SO_2, NO_x, dioxins and furan. These emissions are hazardous to human health and can cause serious damage to the environment. By employing proper design and management, the negative impacts of these emissions can be diminished or reduced to a safe level.

3.2. Sustainability evaluation results

The results obtained from the RIAM analysis were in line with the sustainability evaluation in this study. The results showed that two options out of the four project options (3,4) were considered as very weak sustainable options (Table 6). The remaining two options (1,2) were found to be very weak unsustainable considering their determined S-values. In fact, it can be said that the current situation of the landfill is unsustainable. Option 1 had the S-value of (-0.263), which represents very weak unsustainability. This option is the current situation of the landfill with enormous detrimental effects on the environment. Its current condition would require considerable management, time, and resources to become sustainable. However, the broad spectrum of negative impacts indicated that this option would lead to improper use of the existing resources and should be eliminated. Option 2 was deemed as very weak unsustainable, which was based on the obtained E-value of (0.418) being lower than the obtained HNI-value of (0.506). The main reason for this score could be attributed to the overall significant impact on the environment due to consequent adverse effects on PC and BE components such as the effect on the local population and also leachate contamination due to 20% buried wastes.

Table 6. Summary of Relative ES value and assessment of sustainability for project options.

		Option 1	Option 2	Option 3	Option 4
Relative ES	∑PC	516	639	704	742
	$\sum PC_{max}$	1512	1512	1512	1512
	∑BE	481	808	952	952
	$\sum BE_{max}$	1944	1944	1944	1944
	∑SC	599	706	774	774
	$\sum SC_{max}$	1512	1512	1512	1512
	∑EO	756	786	802	806
	$\sum EO_{max}$	1512	1512	1512	1512
E		0.288	0.418	0.479	0.490
H_{NI}		0.551	0.506	0.478	0.477
Sustainability / Unsustainability	S-value	-0.263	-0.088	0.001	0.043
	S-level	Very weak unsustainability	Very weak unsustainability	Very weak sustainability	Very weak sustainability

Option 3 was deemed sustainable at a very weak level. Its determined S-value was (0.001), which was based on the obtained E-value of 0.479 and was greater than the obtained HNI-value of 0.478. Such an obtained S-value could be reasonably considered as barely sustainable. However, the obtained E-value and HNI-value moderately indicate severe impacts on the environment and humans. This option has the potential to control or reduce some of the pollutants in the environment and significantly reduce their negative impacts on humans and animals, but the final stability is negligible. Option 4 has the S-value with a (0.043) score, which was consistent with very weak sustainability. It was indicated that the positive effects and negative impacts balanced themselves out slightly in favor of positive effects. Based on the result, this option had only six negative impacts, as shown in Table 4 and Figure 2. The most significant positive effects were electricity generation, work opportunities, reduction in pathogen impacts, and a decline in the cost for the collection of leachate. In this study, the RIAM method was used to evaluate the different options for the landfill, and then the value and rate of sustainability of each option were examined. An overview of the results indicated that the results of RIAM were consistent with the results of the sustainability evaluation. Option 4had a higher rating than other options and was the most favorable option based on the results and in terms of sustainability. Based on the obtained results, Option 1 in both assessment methods is an unsuitable approach. Various hazardous pollutants could be entered through implementation of option 1, with adverse impacts on the physic-chemical, biological and ecological components [10,35]. The lack of public acceptance and a low level of safety and public health could lead to a decrease in the socio-cultural score.

4. Conclusions

Its primary purpose is to identify, evaluate, and predict the chemical, physical, economic, and social effects of existing activities in an environmental project and its alternatives. Integration of the RIAM technique with mathematical modeling for evaluation of sustainability provides a reliable tool to assess the applicability of different waste disposal options. This paper has demonstrated an integrated assessment with theoretical and practical rigor, as exemplified by the case study of the landfill options in Kish Island, Iran. The results show that initiating several steps can be very effective in reducing recycling costs and the pollution caused by waste disposal: provide a proper barrier around the disposal site that will prevent the scattering of wastes such as papers and plastics and prevent the turtles from choking; applying an appropriate system of collection and treatment of leachate from the landfill to prevent its influence on the soil; and encouraging people to separate waste from the origin(the effective volume of waste in Kish Island is dry (65%).Based on the findings of this research, it is suggested that the actual socio-economic impacts of waste incineration in tourist islands such as Kish Island can be assessed in future studies.

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