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Suitable landfill site selection for Al-Diwaniyah city using geographic information system

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A B S T R A C T

One of the main problems in the city of Diwaniyah is finding suitable places for burying waste. Geographic Information System (GIS) is an appropriate tool used for this purpose. The city of Diwaniyah, like other Iraqi governorates, is not equipped with an organized system for burying urban waste. The main objective of this study is to find the optimal site for the landfill in Al-Diwaniyah City. For this purpose, and by using the multi-criteria decision analysis (MCDA) known as the Analytical Hierarchy (AHP) in the GIS environment, eleven criteria were presented in the first phase according to international determinants and standards and in line with Iraqi standards. The environment, which is (river, slope, agricultural land use, groundwater, railways, power line, roads, soil types, city center, gas pipeline, and villages) through which a map was developed and produced for each standard using several tools and models in GIS environment, in the second phase, we resorted to the capacity improvement program matrix to assess the weights of the eleven criteria. The study concluded two landfill sites Using the spatial analysis tool "Weight Overlay", the first site is located at coordinate UTM (502241.5, 3537336.2) east of the city, with an area of about 18.89 km2, while the second site is located at coordinate UTM (503371, 3528215.7) to the south of the city, with an area of about 20.64 km2.

1. Introduction

All wastes from social and animal actions that are typically solid and are thrown away as unnecessary or unwanted are collectively referred to as solid wastes (SW). Solid waste can contribute to pollution where pollution is considered as the presence of energy or substances in the form that be harmful for humans and other living organisms.[1] The phrase "solid waste" refers to the more uniform accumulation of industrial, agricultural, and mineral wastes and the heterogeneous mass of throwaways from the urban community. Proper waste management necessitates dealing with solid and other wastes to ensure society's health and the environment's safety by utilizing an integrated system that considers various factors, components, and interconnected circles. This necessitates adapting to the conditions and available resources to meet standards and ensure environmental safety at the lowest possible cost while adhering to legislation and regulations. [2]. A discipline known as solid waste management (SWM) is concerned with regulating the production, storage, collection, transfer and transport, processing, and disposal of solid wastes in a way that adheres to the best practices in public health, economics, engineering, conservation, and is also sensitive to the attitudes of the general public. six functional elements: 1/waste generation; 2/waste handling and separation, storage, and processing at the source; 3/collection; 4/separation, processing, and transformation of solid wastes; 5/transfer and transport; and 6/disposal.[3]

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The wide-ranging national development plans in Iraq have recently improved the social and economic conditions of the populace, which has increased the production of solid waste from various sources and raised the demand for this service. Due to improper disposal practices, the issue of solid waste affects both humans and the environment. The proper foundation must be laid because waste solid management is a significant source of air pollution through the spread of repulsive odors and groundwater and surface pollution. To protect the environment and human life when dealing with the issue of solid waste. [4]. The landfill is the most popular way to dispose of solid waste, and it has benefits and drawbacks just like other methods of treatment. The main drawbacks of open dump solid waste disposal include public health issues, aesthetic issues, and uncontrolled leachate and gas production. To reduce the issues connected to landfill practices, many different types of research were conducted. There has been a lot of interest in advancing landfill technology from a storage/containment concept to a process-based approach, or as a bioreactor landfill, to better understand landfill behavior and the decomposition processes of MSW. Because MSWs degrade slowly in sanitary landfills, bioreactors are a novel idea in solid waste management. In contrast to a sanitary landfill where the leachate is drained out, bioreactors are healthy landfills that encourage microbial degradation and make clear the use of microbial processes to transform and stabilize the components of biodegradable organic waste in a short amount of time. In contrast to sanitary landfills, bioreactor landfills are built to maximize water penetration. By regulating the waste's moisture content and recovering food and seed microorganisms through a leachate recirculation system, bioreactor landfills speed biodegradation to stability.[5]. Geographic Information Systems (GIS) and remote sensing have been implemented as successful and effective tools in recent years to solve the issues with landfill site selection, along with analysis hierarchical process (AHP) for decision-making for the most suitable location for solid waste disposal. With this setup, you can choose a site more quickly and affordably while also getting access to a digital data bank for ongoing site monitoring. AHP is a structural chain technique created to assist people in dealing with complex decisions rather than dictating the "right" choice through analysis of the hierarchical process of making the "right" choice.

2. Study area

Administratively speaking, the research area is located in the Al-Diwaniyah Governorate, namely in the geographic center of the governorate. the research area is situated between two longitudes (44°50, 45°9) and my display circles (31°52, 32°4), with an area of 436.393707 square kilometers Figure 1. 25 meters above sea level, and is one of the cities in southern Iraq and the Middle Euphrates area, regarded as the administrative, economic, and political heart of the Al-Diwaniyah Governorate. This is so because it houses all of the governmental and administrative entities. It is around 180 kilometers from Baghdad and is crossed by the Shatt Al-Diwaniyah, a branch of the Euphrates River. Diwaniyah's climate varies from hot and dry in the summer to cold and dry in the winter. The annual amount of household waste produced by Diwaniyah's majority of urban residents is rising. Most likely, this trend will persist. Because this garbage contains a sizable amount of biowaste and organic stuff, the Diwaniyah is forced to deal with difficulties in its storage and disposal. There is now neither treatment nor oversight of the process; waste is just dumped at landfills selected at random in areas close to urban centers. This may pose a serious risk to the public's health.

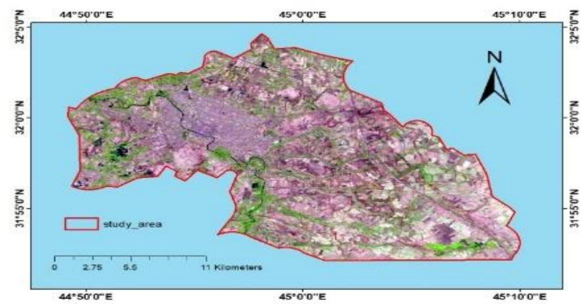

Figure.1 Study area Al-Diwaniyah city (Author, using a program ArcGIS 10.5)

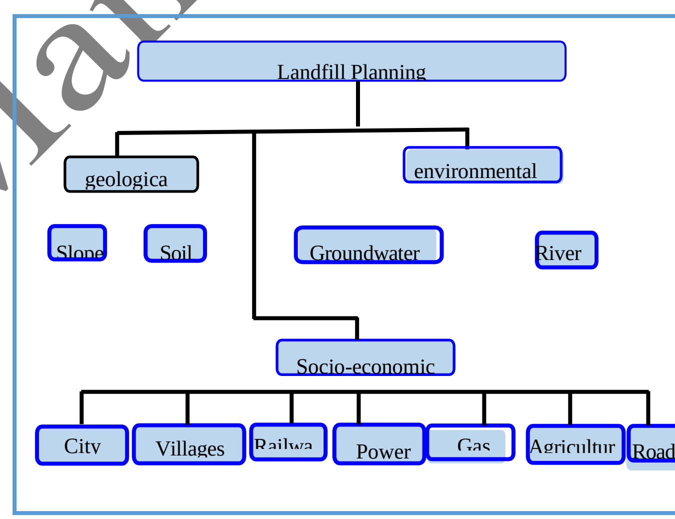

Figure 2: Landfill Planning Criteria

3. Materlals and methods

This type of research was conducted using the geographical analysis of the GIS framework. In addition to the Analytical Hierarchy Processes (AHP).[6] To choose the most appropriate sanitary landfill site in the city of Al-Diwaniyah using the GIS program, several criteria (environmental, geological, economic, and social criteria) were taken into account, as shown in Figure 2.

3.1. Determine and formulation of criteria.

The local circumstances of the area and the layers that have been gathered from the area are taken into consideration while choosing the ideal locations to build landfills. Topography, slope, land use, and other layers are among those where values from 1 to 10 are defined and given new values. All of these values are displayed in Table 1.

Table 1: The levels of the specified criteria

Criteria	Sub.Criteria	Sub.Criteria rating
River	Zone Buffer 0-1 km	0
	Zone Buffer > 1km	10
Slope	0-5	10
	5-10	5
	>10	0
Agricultural Land Use	agricultural land	0
	Unused lands	10
	low-density lands	5
Undwater	3-4m	10
	2-3m	5
	1-2m	3
	1m	1
Railway	Zone Buffer 0-500m	0
	>500m	10
Power line	Zone Buffer 0-30m	0
	>30m	10
Road	Zone Buffer 0-500m	0
	Zone Buffer >2km	3
	Zone Buffer 500m-750m	7
	Zone Buffer 1-2km	5
	Zone Buffer 750-1km	10
Oil types	River shoulder soil	9
	Basin River Soils	7
	Sandy Soil	3
City Centre	Zone Buffer 0-3 km	0
	Zone Buffer 3 – 6 km	10
	Zone Buffer 6-9 km	7
	Zone Buffer >9 km	5
Gas pipeline	Zone Buffer 0-250m	0
	>250m	10
Villages	Zone Buffer 0-1000 m	0
	>1000m	10

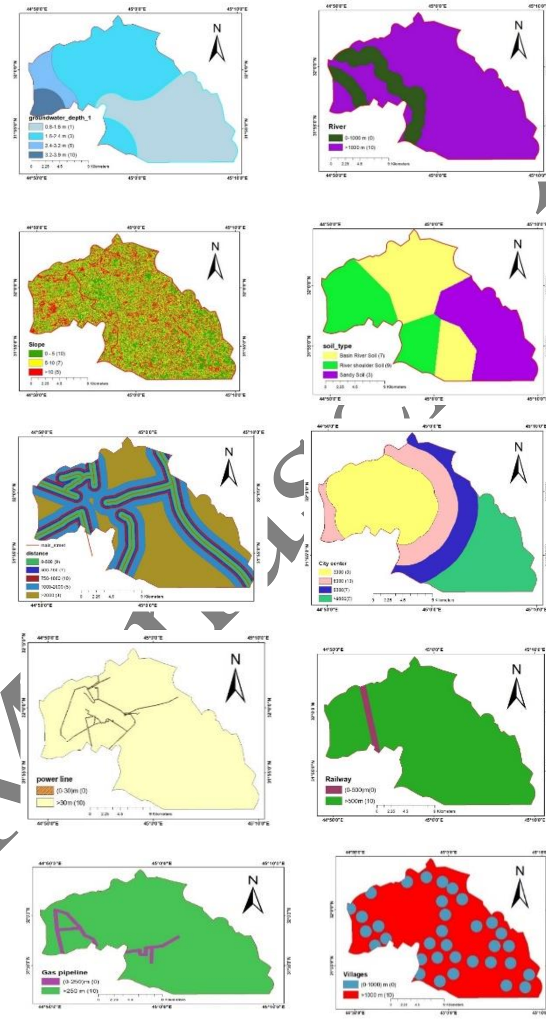

Figure 3. Individual Map of 11 selected criteria

3.2. Calculating the weights of evaluation criteria using the AHP method.

The Analytic Hierarchy Process, sometimes known as the AHP, is a methodology that was developed by Saaty in 1980 and is a strong, comprehensive approach to making decisions. It is one of the methods employed most frequently in the decision-making process, which includes several criteria. Through this strategy, a decision-maker can select the optimal alternative by factoring in their own opinions and factual evidence. [7].

The Analytic Hierarchy Process (AHP) is a method for decomposing hierarchies into a series of pairwise comparisons. This makes it possible for the other criteria to identify the relative weighted importance of each criterion. The degree to which one criterion is more significant than another criterion about the criteria is expressed using a 9-point numeric scale in a standard analytic hierarchy. One criterion's dominance over another can also be used to describe this. This scale was first introduced by Saaty in

1980. Numbers make up the typical framework of the decision-making problem in this investigation, which is formed and organized in a particular way. These numbers were denoted by the symbol m, and a number denoted by the symbol n was assigned to each choice. The calculation incorporated both sets of numbers. Aij values are displayed as "j = 1-2- 3...., n" and "I = 1-2-3, m" respectively. These values describe the performance of the value stated, using the i-th and j-th positions of the matrix as examples. The evaluation criteria values are in the top triangular of the matrix, which is located just above the diagonal. To complete the filling of the matrix's lower triangular, it is necessary to utilize the reciprocal values of the top diagonal of the matrix. To do this, use equation (1) as shown below:

$$aji = 1/aij \tag{1}$$

where (aij) is a component of the matrix's row I and column (j). In a decision matrix, the typical comparison matrix for the relative weight of the criteria can be shown as follows: [8].

The eigenvectors for each row are obtained by multiplying the values for each criterion in each column in the same row of the initial pair-wise comparison matrix and then applying this to each row. This is demonstrated as follows:

$$Egi = (a11 \times a12 \times a13 \times a14 \ldots \times a1n)^{1/n} \tag{2}$$

where n is the number of elements in a row and Egi is the eigenvalue i for the row (i)

The priority vector or AHP weight is obtained by dividing the eigenvalue by their sum, and it is calculated as follows:

$$Pri = Egi / \{\textstyle\sum^{n}_{i=1} Egi\} \tag{3}$$

The maximum value of lambda was determined by adding up the products formed between each element of the priority vector and the total number of columns in the reciprocal matrix, as shown in the following equation (4). The maximum value of lambda was calculated as a result.

$$\lambda max = \textstyle\sum ni=1 [wj * \textstyle\sum mi=1\ aij] \tag{4}$$

Wherein aij is the total of all criteria found in each column of the matrices; Wi is the amount of the weight assigned in the decision matrix, to each criterion that corresponds to the priority vector; and the variables {j = 1-2-3, n} & {I = 1-2-3, m}, respectively. Therefore, this study's maximum lambda is 11.77.

The consistency index (CI) was computed with the help of the equation (5) that is shown below:

$$CI = (\lambda max - n)/(n - 1) \tag{5}$$

where CI is the consistency index, and n is the size or order of the matrix.

CI=(11.77-11)/(11-1)= 0.077

The consistency ratio (CR) is obtained by dividing the consistency index value (CI) by the random index value, here (RI = 1.51), and n is the size of the matrix (n = 11). **Table 2** shows the mean random index value RI for a matrix with different sizes

$$CR = CI/RI \tag{6}$$

CR-= 0.077/1.51= 0.05<0.1 OK

In this study, RI11 = 1.51 and CR = 0.05. CR should be less than 0.1 because, if CR is less than 0.1, the ratio indicates a reasonable consistency level in the pairwise comparison.

Table 2: Random inconsistency indices for different values of (n) [9]

n	1	2	3	4	5	6	7	8	9	10	11	12	13
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56

If the value of CR is less than 10%, the ratio in the pair-wise comparison has demonstrated a high level of consistency. The results of this study indicate that RI11=1.51 and CR=0.05<0.1. The judgments are entirely consistent for any matrix if a CR equals zero [10]. The pair-wise comparison matrix and relative relevance weights used to select a landfill located in the study area are shown in **Table 3**.

However, the WLC technique was used to calculate the appropriateness index value for the potential locations (weighted linear combination). Using the following equation as a basis:

$$Ai = \textstyle\sum n\ Wj * Cij \tag{7}$$

where the appropriateness index for the area is represented by A i. W j is the weighted average of each factor's importance, C ij is the area rating value based on factor j, and n is the sum of all the factors used. [11]. This equation (7) was applied to each criterion using the GIS expansion tool called "map algebra." The suitability index was calculated by summing the results of multiplying the sub-criteria grading values for each criterion (based on the assessments of industry experts) by the relative importance weights that corresponded to those sub-criteria (which were calculated by the AHP method). Using a grading system ranging from 1 to 5, with 1 denoting an unsuitable site and 5 denoting the site that is most suitable for use, the suitability index was calculated. As a result, it was possible to calculate a number accurately representing the site's suitability.

Table 3. Criteria Matrix for Selecting the best landfill

Criteria	City center	Villages	River	Ground water	Slope	Soil type	Road	Land use	Gas pipeline	Power line	Railway	Egi	Pri
City center	1/1	2/1	2/1	3/1	4/1	5/1	6/1	7/1	8/1	8/1	9/1	4.12	0.250
Villages	1/2	1/1	1/1	2/1	3/1	4/1	5/1	6/1	7/1	7/1	8/1	2.94	0.177
River	1/2	1/1	1/1	2/1	3/1	4/1	5/1	6/1	7/1	7/1	8/1	2.94	0.177
Groundwater	1/3	1/2	1/2	1/1	2/1	3/1	4/1	5/1	6/1	6/1	7/1	2.04	0.123
Slope	1/4	1/3	1/3	1/2	1/1	2/1	3/1	4/1	5/1	5/1	6/1	1.43	0.086
Soil type	1/5	1/4	1/4	1/3	1/2	1/1	2/1	3/1	4/1	4/1	5/1	1.00	0.060
Road	1/6	1/5	1/5	1/4	1/3	1/2	1/1	2/1	3/1	3/1	4/1	0.70	0.042
Land use	1/7	1/6	1/6	1/5	1/4	1/3	1/2	1/1	2/1	2/1	3/1	0.49	0.030
Gas pipeline	1/8	1/7	1/7	1/6	1/5	1/4	1/3	1/2	1/1	1/1	2/1	0.34	0.020
Power line	1/8	1/7	1/7	1/6	1/5	1/4	1/3	1/2	1/1	1/1	2/1	0.34	0.020
Railway	1/9	1/8	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1/2	1/1	0.24	0.015

Table 4. Resulting weights

Criteria	Weights
City center	0.25
Villages	0.177
River	0.177
Groundwater	0.123
Slope	0.086
Soil type	0.06
Road	0.042
Land use	0.03
Gas pipeline	0.02
Power line	0.02
Railway	0.015

In this research, priorities, ranks, rates, and weights are given based on a review of etiquette and various personal judgments including expert ideas. The distance to cities and villages takes the greatest importance for maintaining the general health of the people, followed by the depth of canal waters and rivers to prevent pollution, and the reasoning of the study is level, so the slope took less importance. As for land use, the distance from roads, gas pipelines, power, and railways took less importance, and **Table 4** shows the weights of the Criteria. In evaluating the Al-Diwaniyah city landfill's suitability.

4. Results and discussion

4.1. Result of Final Map

The weighting for each criterion was determined using the AHP method, which considered an expert's judgment, prior research in the field, and a variety of necessary and readily available data relevant to the criterion in question. The sub-criteria for every criterion were weighted based on the findings of the current investigation. Using a geographic information system, the overlapping study of potential locations was addressed to find a solution to the problem of finding landfill sites in Al-Diwaniyah. In this process, eleven-layer maps. The final map of the landfill suitability index was then created using a specialized analytical tool called "Weighted Overly." The GIS environment served as the context for this. The suitability of the numerous chosen landfill sites led to the segmentation of the resulting map into four distinct groups. Unsuitable, Suitable, and Most Suitable Locations.

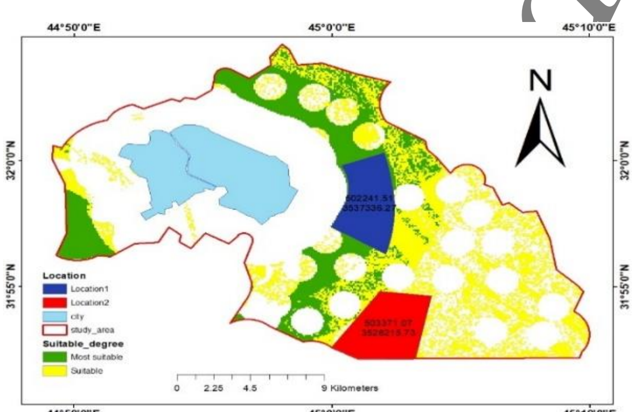

Figure 4. Suitable locations for landfills, the researcher's work using a program ArcGIS 10.5

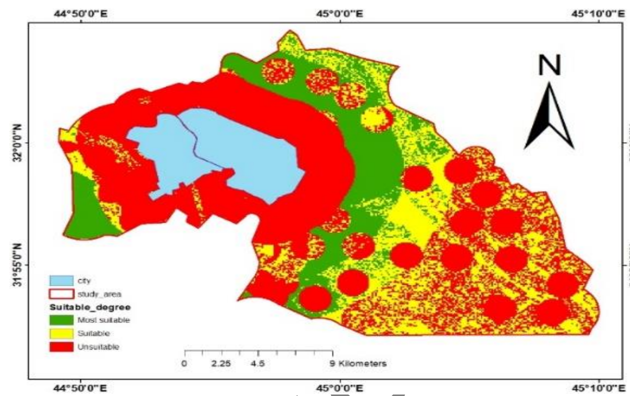

Figure 5. Shows the degrees suitable for the landfills' final project.

Table 5. Summaries of areas and proportions for landfill maps' suitability index

NO	Category	AL-Diwaniya district	
		Area Km2	Proportion%
1	Most suitable areas	71.596	16.43 %
2	Suitable areas	104.495	23.982 %
3	Unsuitable areas	259.621	59.585 %

4.2. Selection of Suggested Sites for the Landfill.

After completing the appropriate map, the proposed sites for burial are chosen in the areas that represent the most suitable and suitable areas on the map, as in (**Figure6**, **Figure7).**

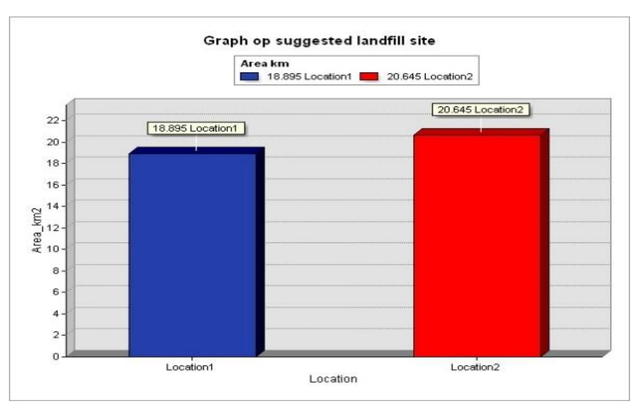

Figure 6: Suggested landfill sites

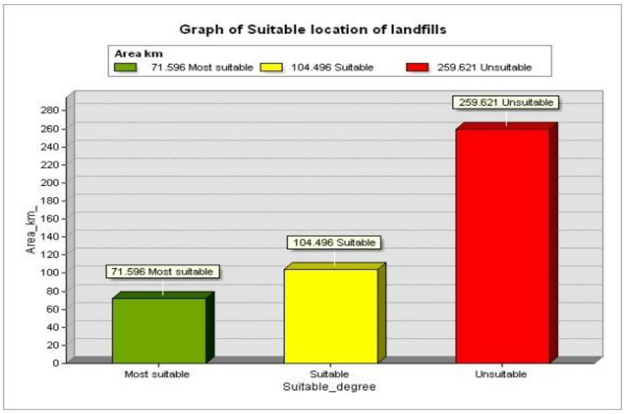

Figure 7. Area of suggested landfill sites

4.3. Estimation of the Amount of Solid Waste in 2040 and the Area of the Landfill.

To estimate the amount of waste in the city of Diwaniyah for the year 2030 we estimate the population for this year and calculate the rate of waste generation per person, as shown in **Table 6**. The landfill area is calculated by estimating the volume of waste generated for this purpose, assuming that the depth of the landfill is (2 m) and the density is 450 kg/m3 **Table 7**.

Table 6. The estimated amount of solid waste produced.

City	Population 2022	Population 2040	Solid waste generation rate (kg/day/capita)	the accumulated waste 2040(Ton)
Al- Diwaniyah	484676	742764	1.31	6305175

Table 7: The space required for the selected sites of 2022-2040

City	the accumulated waste (Ton)	Waste volume (m3)	Required area (m2)	Required area (km2)
Al- Diwaniyah	6305175	14011500	7005750	7.0057

5. Conclusions

1. Integration of multi-criteria decision analysis is a good way to choose a site for a landfill because it makes it easy to manipulate and present spatial data. So, using AHP with GIS and remote sensing technology to find good places to dump solid waste will reduce environmental risks and health problems for people.
2. In this study, eleven map layers were used in the overlay procedure within the GIS and analyzed in the instructions to determine the best suitable unloading site in Al-Diwaniyah city, the criteria are (river, slope, agricultural land use, groundwater, railways, power line, roads, soil types, city center, gas pipeline, and villages).
3. Using the spatial analysis tool "Weight Overlay", the study concluded two landfill sites. The first site is located at coordinate UTM (502241.5 3537336.2), east of the city, with an area of 18.89 square kilometers, and the second site is located at coordinate UTM (503371 3528215.7) south of the city, with an area of 20.64 square kilometers.

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