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Solid Waste Treatment Using Multi-Criteria Decision Support Methods Case Study Lattakia City

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Abstract:

Lattakia city faces many problems related to the mismanagement of solid waste, as the disposal process is limited to the random Al-Bassa landfill without treatment. Therefore, solid waste management poses a special challenge to decision-makers by choosing the appropriate tool that supports strategic decisions in choosing municipal solid waste treatment methods and evaluating their management systems. As the human is primarily responsible for the formation of waste, this study aims to measure the degree of environmental awareness in the Lattakia Governorate from the point of view of the research sample members and to discuss the effect of the studied variables (place of residence, educational level, gender, age, and professional status) on the level of environmental awareness. Data were collected and analyzed using the SPSS.21 statistical package. This study also presents a methodology to find the optimal scenario for solid waste treatment using the hierarchical analysis method represented by Expert Choice 11.1.

The study found that there is an environmental awareness about the danger of the increasing percentage of environmental pollution and the presence of a social willingness to contribute to solid waste management, such as household sorting and working in voluntary associations. Environmental awareness is spreading throughout the province, but more attention is paid to the environment in the countryside than in the city. It was also found that environmental awareness is linked to the cultural level, and it was equal between males and females.

The study also provided the optimal treatment method for solid waste according to the theory of hierarchical analysis, where the biogas production method ranked first with a rate of 35.5%, followed by the composting production method with 22.6%, the recycling method with 17.4%, followed by the incineration method by 15%. The sanitary landfill method ranked last, with 9.5%.

Keywords: Environmental Awareness, Hierarchical Analysis Process AHP, Multi-Criteria Decision-Making MCDM, Municipal Solid Waste MSW, Solid Waste Management.

Introduction:

The problem of waste is escalating daily due to population growth, urban expansion, and the high standard of living. The huge quantities of waste generated pose a real danger to human health as well as to the safety of the environment, causing a heavy burden on municipalities that are unable to process it in many cases [1].

Solid waste is one of the most important environmental issues that countries are currently paying increasing attention to, not only for its harmful effects on public health and the environment but also for its social and economic effects [1, 2]. Human beings are primarily responsible for the formation of waste. Their activities are the main reason for the increased concentration of heavy metals and soil pollution[3]. Any municipal solid waste management program must take into account the role of environmental awareness among citizens, as the presence of environmental awareness is a fundamental necessity for its importance in reducing the costs of MSW treatment and improving the level of its management, as well as its great role in the success of the efforts of municipalities in treating waste properly to achieve a better environment [2, 4].

The primary goals of sustainable waste management are to protect human health and the environment

and to conserve resources. Other objectives include preventing the export of waste-related problems into the future (e.g., 'clean' cycles and landfills that require little aftercare)[5] and promoting socially acceptable waste management practices [6]. To achieve these goals, decision-makers apply integrated strategies, which consist of many related processes, such as collection, transportation, treatment, recycling, and safe disposal, in order to achieve a balance between environmental, economic, technical, regulatory, and other social factors at acceptable costs [7].

In light of the studies conducted to determine solid waste management strategies, a study was conducted in the United Arab Emirates which compared the processes of incineration, gasification, anaerobic digestion, fertilizers, and land-filling in a bioreactor, and the results encouraged the use of anaerobic digestion and gasification more than other methods [8].

An approach to the sustainable management of MSW in developing countries has been used through life-cycle systematic thinking. The study examined practices in Lebanon as a case study of uncontrolled disposal. Thirty alternative WM systems for waste handling were designed. They were assessed for their environmental and economic benefits to demonstrate the proposed approach of developing waste management systems and selecting alternatives. The results showed that recycling coupled with composting notably reduces the environmental impacts and also showed that different waste compositions play a major role in the environmental performance of a WM system[9].

The Life Cycle Assessment (LCA) approach was applied for MSW treatment in Lattakia city. The results concluded that the best environmental scenario consists of a material sorting facility, recycling of recyclable materials, fermentation of the organic part in an anaerobic digester, utilization of the resulting gas in generating electricity, drying the fermented material to convert it into compost, and then burying the remaining waste that is considered inert waste that will not lead to dangerous emissions [10].

The wrong choice of waste disposal technologies, which represents a major problem in municipal solid waste, has long-term negative effects on environmental development and economic growth [11]. Due to the advantages and disadvantages of different technologies, this problem must be solved by considering many selection criteria in terms of economic, social, and environmental aspects [12]. Therefore, the problem of MSW management can be solved using multi-criteria decision support methods [13].

A comparative study was conducted on MSW management strategies in Vietnam between three major cities, Hanoi, Danang, and Ho Chi Minh, using the Fuzzy DEMATEL method, which is one of the modeling strategies of multi-criteria decision-making methods. The results showed that the MSW management strategies in Vietnam are insufficient. It is ineffective in achieving its goals of public health, environmental improvement, and social satisfaction[14].

The Multipurpose Mixed Linear Programming (MILP) model was used to optimize overall costs and assess risk management for designing a municipal solid waste management MSWM network in Qazvin, Iran. The results showed that the economic costs in the first scenario (gasification, anaerobic digestion AD, and landfill gas recovery systems LFGRS) were more than in the second scenario (incineration, composting, and landfill gas recovery systems LFGRS) [15].

A literature review of the applications of multi-criteria decision-making to support waste management noted that studies using multi-criteria decision-making in solid waste management mostly address the problems related to MSW involving facility location or management strategy [16].

In this context, the fuzzy hierarchical analysis method (Fuzzy AHP) was used to study the selection of suitable sites for the establishment of sewage treatment plants, where it was relied upon the Fuzzy AHP method to extract weights for the criteria used in selecting the sites for treatment plants and use them within the GIS to generate a map of the appropriate sites [17].

The AHP hierarchical method was also used to determine the appropriate locations for the olive mill wastewater distribution. The hierarchical analysis method is an effective scientific tool that helps and supports the decision-making process in determining the most suitable location for applying this method, using a single decision-maker and based on the eigenvectors approach to finding priorities[18].

The researcher sees that Waste disposal is “a unit of disposal, destruction or storage of unwanted industrial, agricultural or household products and materials.” It also involves the disposal or disposal of waste materials in accordance with the local environmental regulatory framework, since waste disposal includes a myriad of Operations such as collection, transportation, dumping, recycling or wastewater treatment are among the measures to control and regulate other waste products there are many problems associated with waste disposal.

This research focuses on the use of the hierarchical analysis method AHP, which depends on several

criteria in decision-making, to address the problems related to the mismanagement of solid waste in Lattakia city. This research also measures the degree of environmental awareness among citizens, which plays a great role in the success of the solid waste treatment process.

Materials and methods:

1. Statistical Analysis

The sample size was determined based on a mathematical formula. Kerjcie and Morgan determined the sample size needed to be representative of a given population. At the significance level ($\alpha = 0.05$), the minimum sample size was 384 for a population of one million people[19].

The research community consisted of the residents of the Lattakia Governorate. The number of the applied sample members reached 433 individuals. The sample size was limited to 415 individuals after deleting the questionnaires that were not valid for statistical analysis.

The questionnaire included 225 people from the city and 190 people from the countryside, divided into 133 males and 282 females.

The questionnaire included 40 statements, divided into four criteria (Ecological criterion, Social criterion, Economic criterion, and Technological criterion). Based on the five-point Likert scale (Strongly agree: 5, Agree: 4, Neutral: 3, Disagree: 2, Strongly disagree: 1), the method for making changes was chosen.

This study used the descriptive analytical approach, which allows the analytical study of the various aspects of the phenomenon in describing and analyzing them to achieve the required results. The results were analyzed using the statistical package SPSS.21.

The chi-square test was used to see if the descriptive variables (place of residence, level of educational, gender, age, and professional status) were independent. It had a probability value greater than ($\alpha = 0.05$).

The researcher used the split-half method and Cronbach's alpha equation to ensure the stability of the study tool on a pilot sample consisting of 50 individuals. The stability coefficient by the split-half method before modification was 0.736; then, it was adjusted using the Guttman equation, which shows that the reliability coefficient was 0.745; while the reliability coefficient was calculated using Cronbach's alpha equation, it was 0.834, which is a statistically high stability coefficient.

The Pearson correlation coefficient was calculated for the studied criteria. The ecological and social criteria were the most strongly correlated with a value of 0.68. In contrast, the technological and economic criteria were the least correlated, with a value of 0.45.

Finally, data were collected and analyzed using the package program Statistical SPSS.21. This study also presents a methodology for finding the optimal scenario for solid waste treatment using the AHP hierarchical analysis method.

2. Methodology

Solid waste management is a big problem for decision-makers because environmental problems are getting worse. This shows how important it is to find an analytical framework for making the right decisions about how to treat MSW.

The hierarchical analysis theory was represented in Expert Choice 11.1 (where the comparison matrix is built using the hierarchical analysis methodology, while priority weights are calculated through the Expert Choice decision analysis program) as it fits the issue of making a decision that is affected by many different criteria, as is the case in decisions to find the optimal scenario in MSW treatment.

The theory of hierarchical analysis is an effective means in the evaluation process through its ability to address the problem, build the model, analyze the problem, and find the appropriate alternative, as it is easy to learn and apply [20].

This methodology has spread widely because of Expert Choice, which has an important role in facilitating calculations. Ernest [21] and Saaty [22] programmed Expert Choice in 1983, and Forman [23] developed it in 1998.

2.1. Suggested Methodology Steps

The AHP methodology represented by Expert Choice is based on the following four steps:

A. Problem Modelling
B. Weights Valuation
C. Weights Aggregation
D. Sensitivity Analysis

Finally, this study aims to measure the degree of environmental awareness in the Lattakia Governorate from the point of view of the research sample members, and to discuss the impact of the studied variables (place of residence, educational level, gender, age group, work) on the level of environmental awareness, data were collected and analyzed using the package program.

A. Problem Modelling

The problem was formulated by modelling the hierarchical structure, represented by the following three levels shown in Fig. 1.

1. Goal

The main goal, which is the purpose of presenting the problem, must be determined. In this study, the goal is to find the optimal scenario for MSW treatment.

2. Criteria

The hierarchical analysis is a technique for a structural chain intended to help people deal with complex decisions. Instead of calling them to a "correct" decision, the process of hierarchical analysis helps them make the "correct" decision.

The hierarchical analysis method allows the formation of a hierarchical structure of criteria, which enables experts to focus on main criteria and sub-criteria when setting weights better.

Several studies and international standards for evaluating treatment processes were reviewed. A set of criteria were deduced that influence selecting the optimal scenario for MSW treatment and are categorized in Table 1.

3. Determine the alternatives

One of the data analyses tools and methods that are used to evaluate specific options or methods that are already available, as one of them is considered an alternative to the other before the analysis, in order to make a decision that determines the choice of one of these alternatives to be the method that will be used to implement one of the project's works.

The following alternatives have been proposed, in line with the reality of the studied area: incineration, recycling, biogas production, composting production, and sanitary landfills.

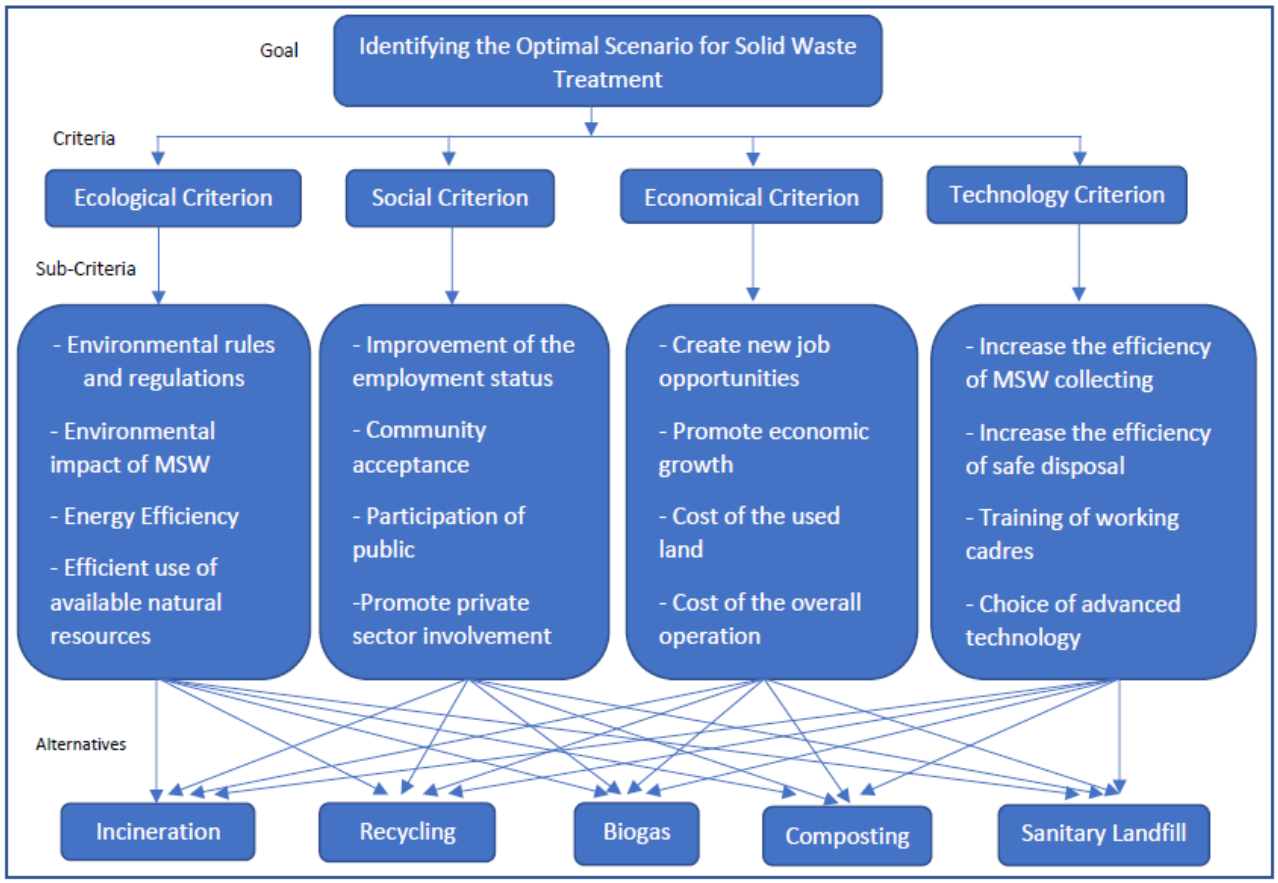

Figure 1. Hierarchical Structure

Table 1. Main criteria and sub-criteria of the proposed model.

Ecological criterion	Social criterion	Economic criterion	Technological criterion
Environmental rules and regulations	Improvement of the employment status	Create new job opportunities	Increase the efficiency of solid waste collecting and transporting
Environmental impact of solid waste treatment methods	Community acceptance and satisfaction	Promote economic growth and sustainable development	Increase the efficiency of safe disposal of the waste treatment process
Energy Efficiency in processing treatments	Participation of public and voluntary organizations	Cost of the used land	Training of working cadres
Efficient use of available natural resources	Promote private sector involvement	Cost of the overall operation	Choice of advanced technology

B. Weights Valuation

1. Pairwise Comparisons

After the formation of the hierarchy, pairwise comparison between criteria concerning the goal, between sub-criteria with respect to the relative criterion, and between alternatives for all sub-criteria is conducted, which leads to the formation of judgmental matrices. The judgments are based on a standardized comparison of Saaty's scale of nine levels, given in Table 2 [24]. Furthermore, AHP methodology has been utilized to determine alternatives' priorities to solve the judgmental matrices. The local priority vector (PVE or w) for the matrix judgments is obtained by normalizing the vectors in each matrix column, then by computing the average of the resulting matrix rows[25].

Table 2. Saaty's nine-point scale for pairwise comparison.

Numerical rating	Verbal judgments of preferences between alternatives i and alternatives j
1	i is equally important to j
3	i is slightly more important than j
5	i is strongly more important than j
7	i is very strongly more important than j
9	i is extremely more important than j
2, 4, 6, 8	Intermediate values

2. Consistency Check

This ensures that the pairwise comparison judgments are sufficiently consistent by computing the consistency ratio CR. First, calculate the principle eigenvalue (λ_{max}) for each matrix using eq.1.

$$A\,w = \lambda_{max}\,w \quad (1)$$

where A is the comparison matrix, λ_{max} is the principle eigenvalue, and w is the normalized right eigenvector (priority vector). Second, estimate the consistency index CI for each matrix with the dimension n using eq.2.

$$CI = \frac{\lambda_{max}-n}{n-1} \quad (2)$$

Then finally, calculate the CR using eq.3.

$$CR = \frac{CI}{RI} \quad (3)$$

where RI is the random index. The value of RI is selected depending on the dimension of the comparison matrix n. Table 3, illustrates the different RI values for matrices having order n from 1 to 10. The acceptable limit of CR values depends on the size of the matrix. For example, the acceptable CR value for 3 × 3 matrix is 0.05, 4 × 4 matrix is 0.08, and for matrices having a size ≥5 × 5 matrix is 0.1[26].

Table 3. Random index (RI) values for different matrix sizes.

Matrix Size n	1	2	3	4	5	6	7	8	9	10
Random Index	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

C. Weights Aggregation

The global priorities for each alternative are determined by synthesizing the local priorities over the hierarchy using eq.4.

$$P_i = \sum_j w_j * l_{ij} \quad 4$$

Where P_i represents the global priorities and l_{ij} represents the local priorities.

After unpacking the questionnaire data, and arranging it, the questionnaire data is prepared to analyze this data by several statistical operations to reach the results that the researcher wants to use in scientific research. on the results of the questionnaire data.

D. Sensitivity Analysis

Expert Choice software enables better sensitivity analysis with an interactive schematic interface by performing sensitivity analysis through different schematic representations. The program includes five types of sensitivity analysis: performance, dynamic, head-to-head, gradient, and two-dimensional sensitivity.

Results and discussion:

1. Statistical Analysis

The questionnaire was analyzed in the form of several questions:

1- What is the degree of environmental awareness about MSWM in the Lattakia Governorate from the point of view of the research sample members?

Table 4, shows the average, standard deviation, and relative weight for each phrase in the environmental awareness questionnaire about MSWM and for the whole questionnaire.

Table 4. The answers of the research sample to the degree of environmental awareness about MSWM.

Ranking	order	Relative weight	Std. deviation	Mean	Statements	Criteria
Strongly agree	23	85%	0.77	4.25	1- I think the best way to deal with waste is to reduce its generation or production	**Ecological Criterion**
Strongly agree	5	92.8%	0.51	4.64	2- I am concerned about the increasing level of pollution in the environment	
Strongly agree	16	87.6%	0.64	4.38	3- I think that waste resulting from the Corona epidemic is a new problem whose effects will appear in the future	
Agree	39	74.8%	0.82	3.74	4- Ready to buy recycled goods	
Strongly agree	14	88%	0.69	4.4	5- Willing to donate unnecessary materials or products to private recycling organizations	
Strongly agree	3	94.2%	0.51	4.71	6- I feel comfortable moving solid waste away from my residential area	
Strongly agree	17	87.6%	0.71	4.38	7- I think that reducing the consumption of nylon bags and plastic materials reduces the amount of waste generated	
Strongly agree	15	88%	0.73	4.4	8- I have the desire to convert solid waste into organic compost or biogas	
Strongly agree	13	88%	0.67	4.4	9- Ready to separate kitchen waste from other household waste	
Agree	32	79.8%	0.88	3.99	10- Ready to dispense with the use of plastic materials	
Disagree	38	76.2%	0.96	3.81	11- I think incineration of solid waste is the best way to dispose of it	
Strongly disagree	6	92.8%	0.54	4.64	12- I think that throwing solid waste into rivers and seas is the best way to get rid of it	
Agree	40	70.8%	1.05	3.54	13- I think sanitary landfill of solid waste is the best way to dispose of it	
Strongly agree	24	84.8%	0.76	4.24	14- I think that fermenting the waste into biogas and using the resulting material as organic compost is the	

					best way to get rid of it	
Strongly agree	2nd	85.02 %	0.313	4.251	**Ecological Criterion**	
Strongly agree	2	94.6%	0.44	4.73	15- I think that the citizen has a role in preserving the environment through their interest in using waste bags and closing them well	
Agree	27	83.4%	0.68	4.17	16- I would like to participate in cleaning campaigns in my neighborhood	
Agree	30	81%	0.69	4.05	17- I would like to work for a voluntary association to protect the environment	
Strongly agree	9	89.4%	0.58	4.47	18- I believe that the media has a key role in raising awareness among citizens	
Strongly disagree	10	88.8%	0.65	4.44	19- It's okay to put waste near trash containers	
Disagree	33	79.4%	0.83	3.97	20- It's okay to move trash containers out of place	**Social Criterion**
Agree	37	76.2%	0.94	3.81	21- I think the cleaners should take back the recyclables during the waste collection and transportation process	
Agree	36	76.4%	0.92	3.82	22- I think the Corona epidemic has increased the awareness of cleaners to take safety and security precautions	
Strongly agree	11	88.4%	0.6	4.42	23- I think that society's customs and traditions have a great impact on the amount of waste	
Strongly agree	22	85.4%	0.72	4.27	24- I think the difference in the standard of living affects the amount of waste	
Strongly agree	4th	84.28 %	0.333	4.214	**Social Criterion**	
Strongly agree	20	87%	0.58	4.35	25- I think recycled materials have commercial and industrial importance	
Strongly agree	21	86.8%	0.62	4.34	26- I think that recycling waste provides many job opportunities	**Economic Criterion**
Agree	25	84%	0.67	4.2	27- I think that the initial sorting of solid waste is necessary, in case its fees are reduced	
Agree	31	80.6%	0.59	4.03	28- Ready to sort household waste and sell it when invested	
Strongly agree	19	87.2%	0.55	4.36	29- I think that private sector companies should be contracted to provide waste collection services in hard-to-reach areas	
Agree	28	82%	0.7	4.1	30- I would like to participate in the private sector's cleaning campaigns in the future	
Strongly agree	3rd	84.64 %	0.368	4.232	**Economic Criterion**	
Disagree	34	78.8%	0.89	3.94	31- I think the municipality is doing a good job of collecting waste	**Technology Criterion**
Strongly agree	12	88.2%	0.65	4.41	32- Ready to commit to sorting waste in the designated containers, if the municipality allocates a container for each type of waste	
Strongly agree	18	87.4%	0.56	4.37	33- Ready to commit to waste disposal dates, in case the municipality allocates specific times for waste collection	
Agree	35	78.8%	0.92	3.94	34- I think the Corona epidemic has made it more difficult to manage waste	

Agree	26	84%	0.86	4.2	35- I think that the presence of waste pickers is an obstruction for the municipality in the waste management process
Strongly agree	8	90.2%	0.53	4.51	36- I think that the municipality should use modern and advanced methods of collecting and transporting waste
Agree	29	81.2%	0.79	4.06	37- I think collecting trash in the afternoon is a traffic jam
Strongly agree	4	93.2%	0.51	4.66	38- I think washing and sterilizing containers after emptying is essential to prevent the spread of odors
Strongly agree	7	91.4%	0.55	4.57	39- I think it is necessary to use new technology in waste treatment
Strongly agree	1	96.2%	0.41	4.81	40- I think it is necessary to treat solid waste for generating electricity to solve the problem of electricity shortage in the country
Strongly agree	1st	86.96 %	0.307	4.348	**Technology Criterion**
High degree		85.26 %	0.69	4.26	The degree of environmental awareness of solid waste management

There is a high degree of environmental awareness according to the answers of the sample members, where the arithmetic mean was 4.26 and relative weight of 85.26%.

The technological criterion ranked first with a relative importance of 86.96%, while the social criterion ranked last with a relative importance of 84.28%, according to the members of the research sample.

Waste fermentation and biogas production had the greatest relative importance, with a percentage of 84.8% as the best way to dispose of MSW, followed by the sanitary landfill method with a relative importance of 70.8%, while incineration ranked last with a relative importance of only 23.8% from the point of view of the research sample members.

2- What is the effect of each of the studied variables (place of residence, educational level, gender, age, and professional status) of the research sample members on the level of environmental awareness of MSWM in the Lattakia Governorate?

Multiple Analysis of Variance MANOVA was used to test the model's validity between the independent variables (place of residence, educational level, gender, age, and professional status) and the dependent variable (the level of environmental awareness of MSWM in the Lattakia Governorate). The results are included in the following Table 5.

Table 5. Results of MANOVA test according to the research sample members.

Statistical significance	Sig.	t	Unstandardized Coefficients		Sig.	F	R Square	R	Independent variables	Dependent variable
			Std. Error	Beta						
Statistically significant	0.000	29.538	0.112	3.304					constant	
Statistically significant	0.007	2.717	0.031	0.084					Place of residence	**the level of environmental awareness of solid waste management**
Not statistically significant	0.331	0.973	0.027	0.026	0.000	36.035	0.45	0.67	Gender	
Statistically significant	0.000	4.179	0.023	0.097					Age	
Statistically significant	0.000	13.064	0.014	0.186					Education level	
Statistically significant	0.000	3.672	0.007	0.027					Professional status	

The correlation coefficient was 0.67, indicating a linear relationship with statistical significance between the independent and dependent variables according to the research sample. The coefficient of determination equals 0.45, which means that the studied independent variables affect the level of environmental awareness for solid waste management by 45%, which is closer to half.

There was no effect of the variable (gender) on the level of environmental awareness of MSWM, where the calculated t value was 0.973 with a probability value of 0.331, which is greater than ($\alpha = 0.05$). While there was an effect of the variables (place of residence, educational level, gender, age, and professional status) on the level of environmental awareness of MSWM, the probability value was less than ($\alpha = 0.05$).

3- Are there statistically significant differences in the opinions of the research sample members about the degree of environmental awareness of MSWM due to the variable of the place of residence (countryside, city) at the significance level ($\alpha = 0.05$)?

Table 6, displays the arithmetic averages based on the Independent Samples T-Test of the research sample.

Table 6. T-test results according to the research sample members due to the residence variable.

Statistical significance	Sig.	t	Std. Deviation	Mean	N	Place of Residence
Statistically significant	0.008	2.671	0.218	4.299	190	**Countryside**
			0.286	4.232	225	**City**

There are statistically significant differences between the averages of city and countryside residents, whose averages were the highest at 4.299, as the calculated t value was 2.671 with a probability value of 0.008, which is less than ($\alpha = 0.05$).

4- Are there statistically significant differences in the opinions of the research sample members about the degree of environmental awareness of MSWM due to the educational level variable at the significance level ($\alpha = 0.05$)?

One-way ANOVA was used for multiple comparisons, and the following Table 7, shows the result of this calculation.

Table 7. Results of One-way ANOVA according to the research sample members due to the educational level variable.

Statistical significance	Sig.	F	Std. Deviation	Mean	Education level
Statistically significant	0.000	38.735	0.111	3.794	**Preparatory certificate**
			0.352	3.900	**Secondary certificate**
			0.144	4.112	**Institute**
			0.191	4.312	**University degree**
			0.277	4.342	**Postgraduate**

There are significant and essential differences in the degree of environmental awareness of MSWM due to the educational level variable. The value of F = 38.735 with a probability value of 0.000, which is less than ($\alpha = 0.05$). It was also noticed that the average value of the postgraduate categories went up with a value of 4.342, which was higher than the value of the preparatory certificate categories, which was 3.794. The LSD test was used for dimensional comparisons, as shown in Table 8, to find out how these differences depended on the educational level variable.

Table 8. Results of the LSD test between the average answers of the research sample members due to the educational level variable.

Statistical significance	Sig.	Mean Difference		Education level
Not statistically significant	0.361	0.106	secondary certificate	**preparatory certificate**
Statistically significant	0.013	0.318	institute	**preparatory certificate**
Statistically significant	0.000	0.518	university degree	**preparatory certificate**
Statistically significant	0.000	0.548	postgraduate	**preparatory certificate**
Statistically significant	0.003	0.212	institute	**secondary certificate**
Statistically significant	0.000	0.411	university degree	**secondary certificate**
Statistically significant	0.000	0.442	postgraduate	**secondary certificate**
Statistically significant	0.002	0.199	university degree	**institute**
Statistically significant	0.001	0.230	postgraduate	**institute**
Not statistically significant	0.375	0.030	postgraduate	**university degree**

The differences between the answers of the research sample members were in favor of postgraduate studies in terms of arithmetic averages.

It should be noted that the difference between the averages of both the preparatory and secondary certificate holders, as well as undergraduate and postgraduate degree holders, is not statistically significant due to the convergence of the averages for each of them.

Finally, there is environmental awareness about the danger of the increasing rate of environmental pollution, and the existence of a social willingness to contribute to solid waste management, such as household sorting and working in voluntary associations. Environmental awareness is spreading in the entire governorate, but attention to the environment is noted in the countryside more than in the city. It was also found that environmental awareness is linked to the cultural level, and is equal for males and females**.**

2. Application of AHP

The hierarchical structure was formed in Expert Choice 11.1 in order to choose the optimal scenario for MSW treatment, as shown in Fig. 2.

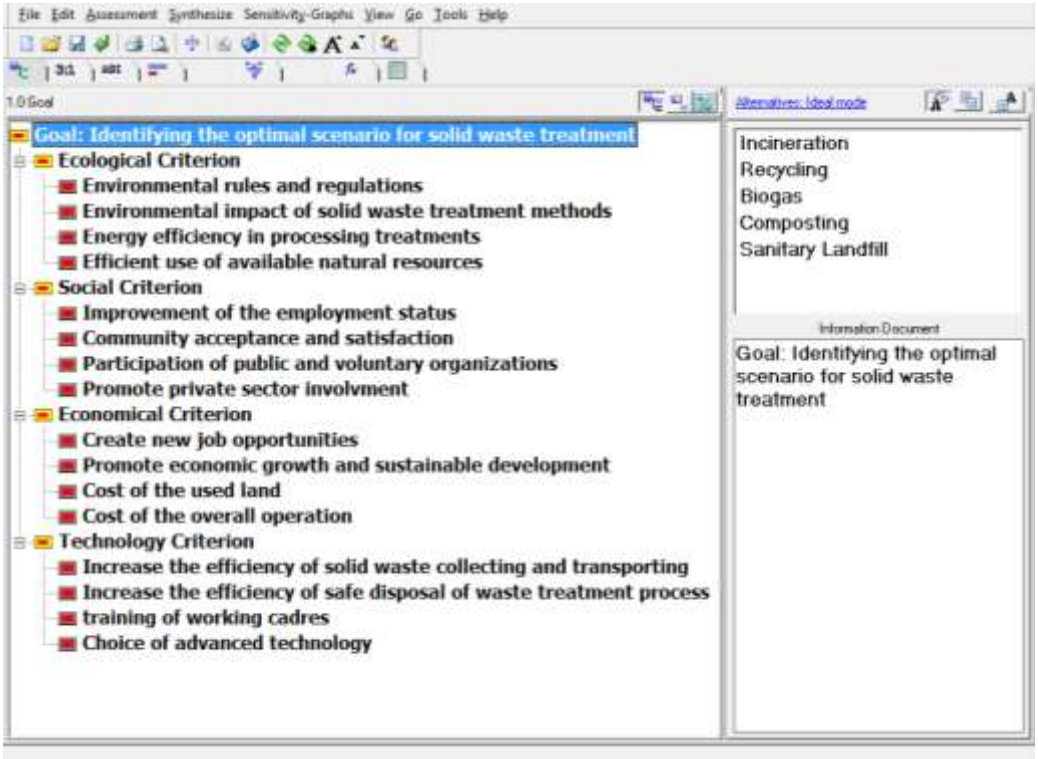

Figure 2. The Input of the hierarchical structure of the proposed model in Expert Choice

The weights of the pairwise comparison for the main criteria, sub-criteria, and alternatives were entered by a committee of seven experts and synthesized to obtain the final result of the proposed model, as shown in Fig. 3.

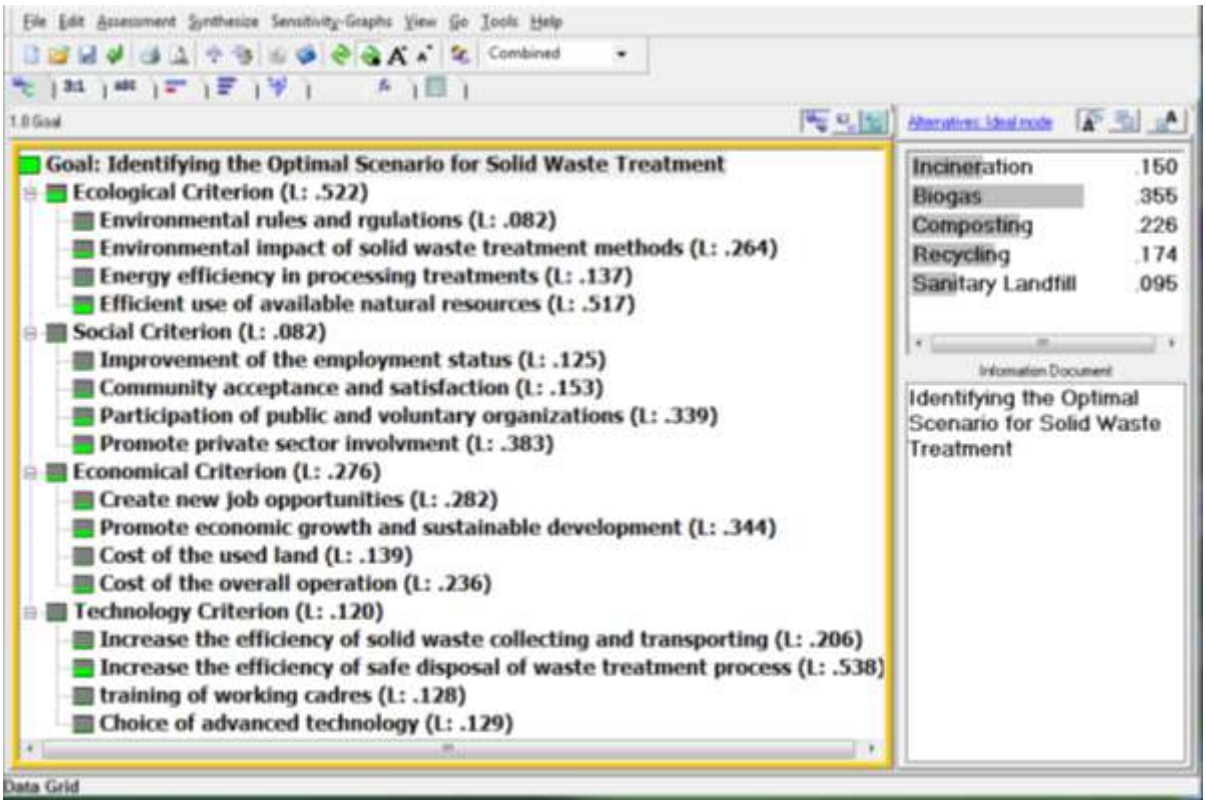

Figure 3. Final results of the proposed model in Expert Choice

The results show that the best alternative is biogas production by 35.5%, followed by the composting production method by 22.6%. The recycling method by 17.4%, followed by the incineration method with 15%, and the sanitary landfill method ranked last, with 9.5%. One of the features of Expert Choice is the ability to display the results through graphs according to several types of sensitivity analysis, as shown in Fig.4. These results are consistent with those obtained by Qazi et al, who found that anaerobic digestion is the best performing option with 23.3%, followed by fermentation with 16.5% for municipal solid waste management in Oman using the AHP hierarchical method[25]. Furthermore, anaerobic digestion contributes to the safe disposal of waste and energy generation[27]. It's the suitable waste-to-energy WTE technology for Manila City, Philippines using the AHP hierarchical method, which compared the processes of anaerobic digestion, incineration, and pyrolysis[28].

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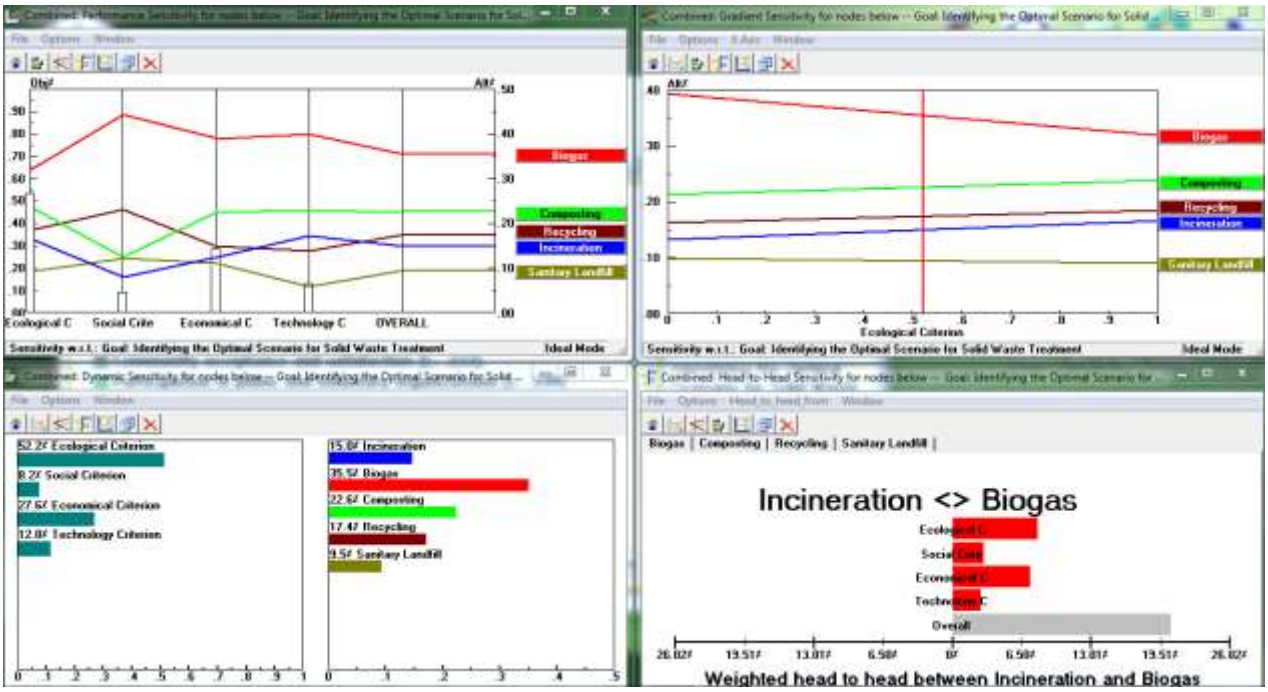

Figure 4. Sensitivity Analysis Graphs showing biogas production is the Best

The ecological criterion ranks first with 52.2%. In comparison, the social criterion ranks last with 8.2%. The order of alternatives remains the same for both the ecological and economic criteria. In contrast, the recycling method becomes second place instead of the composting production method for the social criterion, and the incineration method ranks third place for the technological criterion.

3. Sensitivity Analysis

We will make some modifications to these graphs to clarify the sensitivity analysis. As the importance of the main environmental criterion has been reduced to 17%, the importance of other criteria changes automatically, as shown in Fig. 5.

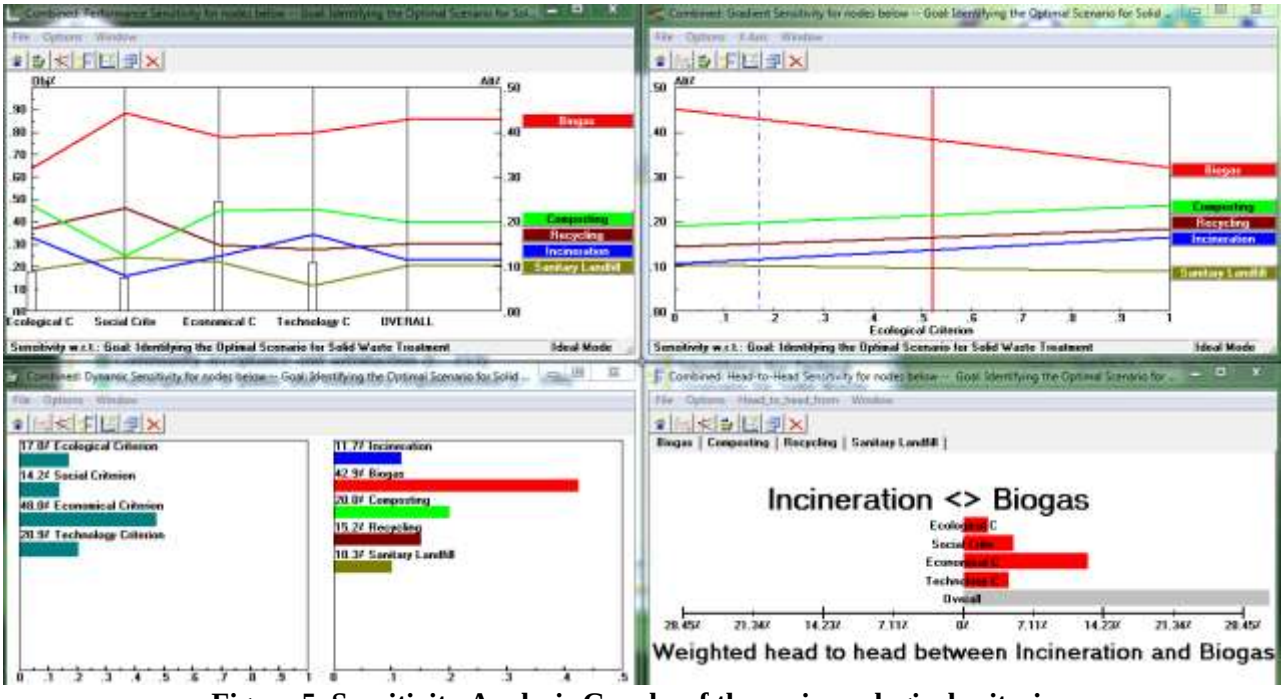

Figure 5. Sensitivity Analysis Graphs of the main ecological criterion

As a result of decreasing the main ecological criterion, the economic criterion exceeds all other criteria by 48%. Nevertheless, the order of the alternatives remains the same, with the biogas

production method leading with 42.9%, followed by the composting production with 20%, the third place was the recycling method with 15.2%, the fourth place was the incineration method with a rate of 11.7%, and in the last place was the sanitary landfill method with a rate of 10.3%.

Conclusion:

As the amount of municipal solid waste continues to increase, the concern is also growing about its safe and effective management.

Effective waste management requires an integrated approach that achieves a balance between production and disposal, starting with reducing waste generation from the source. This largely depends on the degree of awareness of citizens through improving food behaviors and habits on the one hand and their readiness for sorting, recycling, and purchasing recycled goods on the other hand.

Effective waste management is also related to selecting the appropriate technology for disposal, which is a major problem in waste management because there is a need to consider multiple criteria to determine this technology. MCDM methods have been commonly used to solve this problem.

In conclusion, it is necessary to realize the seriousness of environmental pollution in Lattakia city. It should strongly consider the many benefits of the biogas production method for municipal solid waste, as it is the best option for all the environmental, social, economic, and technological criteria. Moreover, it can generate enough electricity to meet all the needs.

Certainly, Expert Choice has facilitated the use of the hierarchical analysis method and contributed greatly to the success of this method. Still, it is necessary to carry out a cost analysis to make the appropriate decision.

Finally, regulating the expanding manufacturing industries, on a daily basis these industries produce toxic products that eventually end up being discarded after use as most of the products contain hazardous and health threatening chemicals.

Authors' declaration:

-Conflicts of Interest: None.

-We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.

-Ethical Clearance: The project was approved by the local ethical committee in department of Environmental Engineering, College of Civil Engineering, Tishreen University.

Authors' contributions:

The first author (Z.Al.) conceived of the presented idea and developed the theory through discussions with the other authors. The second author (R.J.) supervised the study and verified the main and sub-criteria. The third author (H.Sh.) verified the analytical methods. The fourth author (A.Aw.) verified the statistical analysis. The statement of contributions is prepared and approved by the authors.

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معالجة النفايات الصلبة باستخدام طرق دعم القرار متعددة المعايير حالة الدراسة مدينة اللاذقية

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الخلاصة:

تواجه مدينة اللاذقيّة الكثير من المشكلات المرتبطة بسوء إدارة النفايات الصلبة، حيث تقتصر عملية التخلّص منها في مكب البصّة العشوائي دون معالجة، لهذا تشكّل إدارة النفايات الصلبة تحدّياً خاصاً لصانعي القرار باختيار الأداة المناسبة التي تدعم القرارات الاستراتيجيّة في اختيار طرق معالجة النفايات الصلبة وتقييم أنظمة إدارتها. بما أنّ الإنسان هو المسؤول الأول عن توليد النفايات، فإن هذه الدراسة تهدف إلى قياس درجة الوعي البيئي في محافظة اللاذقيّة من وجهة نظر أفراد عينة البحث، ومناقشة أثر المتغيرات المدروسة (مكان الإقامة، المستوى التعليمي، الجنس، الفئة العمرية، العمل) على مستوى الوعي البيئي، تم جمع البيانات وتحليلها باستخدام برنامج الحزمة الإحصائية SPSS.21، كما تطرح هذه الدراسة منهجيّة لإيجاد السيناريو الأمثل لمعالجة النفايات الصلبة باستخدام طريقة التحليل التسلسلي الهرمي AHP ممثّلة ببرنامج.Expert Choice 11.1

توصلت الدراسة إلى وجود وعي بيئي حول خطورة تزايد نسبة التلوّث البيئي، ووجود استعداد اجتماعي للمساهمة في إدارة النفايات الصلبة كالفرز المنزلي والعمل في جمعيات تطوعيّة، كما أنّ الوعي البيئي ينتشر في المحافظة بكاملها ولكن يلاحظ الاهتمام بالبيئة في الريف أكثر من المدينة. كما تبيّن أنّ الوعي البيئي يرتبط بالمستوى الثقافي، ومتساوياً بين الذكور والإناث.

كما قدمت الدراسة طريقة المعالجة الأمثل للنفايات الصلبة وفق نظريّة التحليل الهرمي، حيث حلّت طريقة إنتاج الغاز الحيوي في المرتبة الأولى بنسبة 35.5%، تليها طريقة إنتاج الأسمدة بنسبة 22.6%، ثمّ طريقة إعادة التدوير بنسبة 17.4%، ثمّ طريقة الترميد بنسبة 15%، وحلّت في المرتبة الأخيرة طريقة الطمر الصحي بنسبة 9.5%.

الكلمات المفتاحية: الوعي البيئي، طريقة التسلسل الهرمي AHP، اتخاذ القرار متعدّد المعايير MCDM، النفايات البلديّة الصلبة MSW، إدارة النفايات الصلبة.