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# The fuzzification of mathematical matrix in the environmental impact assessment of steel industry, Ghayen, Iran

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**Abstract**
Ghayenat steel complex is located in South Khorasan province near the Nimbolook city. In this research, the interactions between basic and supplementary criteria are evaluated using a mathematical matrix. The results of the meaningful impact are divided into four categories: low, middle, high, and very high. In this research, the effects of synergism and disagreement among experts are used as quantitative factors affecting environmental impacts in matrix calculations. The results of the mathematical matrix are fuzzyficated using a minimal operator in a triangular diagram. By including the compensating factor, the results of the mathematical matrix illustrate that only low and middle classes have impacts on the environment. Also, high and very high classes have a small share in the impact. On the other hand, according to the results, most activities are related to the middle and low classes for the basic criteria. Most of the interactions are associated with the low impacts on the supplementary criteria. Fuzzification shows that if the compensating factor is not applied, the highest impacts will be in the middle and high classes. If the compensating factor is applied, 0.73% of the impacts will be in the middle class, and the very large class has a small share. Also, due to the impacts of the compensatory criteria, the project is approved in both ways.

**Keywords** mathematical matrix; fuzzy; compensatory criteria; Ghayenat steel.

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## 1 Introduction

The environmental balance impairment is due to various economic and industrial activities, the use of advanced technologies, and the population growth. Evaluating the impacts of development on the environment is an important technique to ensure that the probable impacts of development projects on the environment are entirely identified and calculated (Shariat and Monavvari, 1996). Therefore, developments that are appropriate to the current practice and future potential of the environment must be chosen masterly, considering the fact that many changes should be made on the environment. After evaluating the ecological potential, it is necessary to assess the development impacts on the environment in the process of planning and managing the land for sustainable development (Makhdom, 1999). The implementation of land use projects, including the factories construction and the development of the industries, requires the study of the natural potential of the land for the desired development. In this regard, conducting Environmental Impact Assessment (EIA) studies is one of the methods to achieve sustainable development goals. EAI can be used as a planning tool to determine the project goals matching with environmental laws and regulations (Sharifi et al., 2008).

EIA has become an important tool for promoting the principles of sustainable development and the best available technologies. At present, continuous improvements with new, more efficient and effective methodological and legislative instruments and procedures for such assessments as well as managements are being researched. Topical issues in EIA research include public participation (Smith and Bond, 2018).

The fuzzy method has been used in many fields successfully. The fuzzy logic has been referred to as an information support system in many scientific fields (Zadeh, 1965; Duart et al., 2007). The application of fuzzy logic in EAI is the starting point bias in traditional methods. It has also been used to improve the quality of the evaluation studies. EAI relies on fuzzy information (Duart, 2003). The uncertainty cannot be considered as a separate parameter in EAI. The lack of knowledge, randomness, and variability of natural data cause this problem. It is potential in all of the systems (Daraba et al., 2008). The nature of fuzzy logic is based on the fact that not only is there no relative difference in impacts, but at the same, it contains ambiguity in some quantitative and qualitative impacts. In this logic, the effect of human judgment can be considered under unknown circumstances (Chang et al., 2009). Human activities are more significant than natural self-purification. Prediction of environmental impacts before implementing activities is an appropriate solution to minimize and modify the impacts (Duarte et al., 2007). Evaluating environmental impacts is a tool in the service of development strategies and projects that has been recommended and approved in many countries' programs by many regional groups and International agencies (McInnes, 2018; Danida, 1994).

Environmental Impact Assessment (EIA) is based on a detailed analysis of the expected and other potential impacts on individual components of the environment and the population (Li et al., 2016). The consequences of the adverse impact of the stressor must be examined at different levels. For example, human health damage is usually considered at the individual level, but environmental damage is usually considered at the level of population, species or communities (Martinaet al., 2020).

Two main approaches are recognised from the literature and the case studies to integrating ecosystem services within environmental assessment: firstly a comprehensive approach, where the assessment framework is entirely guided by ecosystem services; and secondly a philosophical approach that applies more of a light-touch ecosystems-thinking mind-set, helping to frame the assessment methodology rather than fundamentally defining it. Inevitably, there are variations between these two extremes, and benefits and criticisms of both (Baker et al., 2013).

In the present situation, Iran is witnessing two major waves of internal and external changes in the field of the environment and its theoretical and practical issues. An international approach to solving environmental problems and the dynamics of political, social and economic developments within the borders has led to the expansion of studies that require that the response to them requiredlooking for infrastructure solution and structured planning at the national and regional levels (Monavari, 2005).

Moron et al. (2009) presented a new fuzzy model in evaluating the impacts. This model can integrate quantitative and qualitative information. A software evaluation called AIEIA has been introduced for this purpose. This software is very efficient for the comprehensive management of the environmental projects. This model is not only used for fuzzy impact assessment studies but also a tool for fuzzy decision making.

Tolga and Kahraman proposed an EIA based on the fuzzy AHP-ELECTRE for the industrial town development plan in 2011. In this method, fuzzy AHP5 has been used to determine the weights of the criteria. Fuzzy logic has been used for environmental factors that have uncertainty and ambiguity. Bojorquez Tapia et al. (2002) proposed the evaluation of ecological effects to improve the mathematical matrix method using fuzzy logic and GIS. They also showed the possibility of reducing the effects by combining the two approaches in an example of the ecological assessment of highway construction. Ahmadizadeh et al. (2011) evaluated the effects of the steel complex using Rapid Impact Assessment Matrix (RIAM). The results showed more positive aspects of the plan rather than the negative ones, especially in Socio-cultural and technical-economic.

## 2 Model

Ghaenat Steel Complex is located in South Khorasan Province, near the city of Semi-Block in geographical coordinates X = 33,5530 North and Y = 590014 East with a total area of 604 hectares. The license for the construction of this complex has been approved with the aim of producing 800,000 tons of light alloy steel ingot per year (Fig. 1).

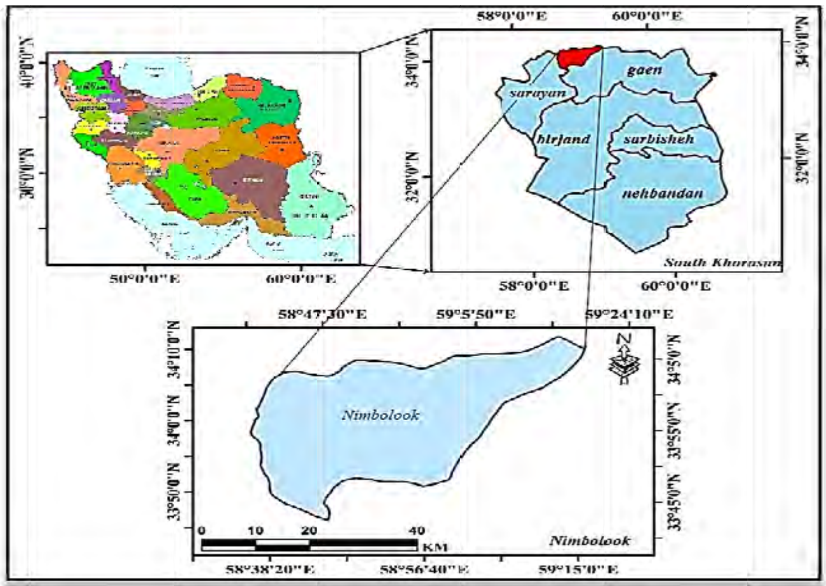


**Fig. 1** Schedule location.

### 2.1 Mathematical matrix research method

The assessment of the effects of development will take several steps to ensure that all predictive effects are taken into account. The usual conditions follow the three stages (Salehi et al., 2012), which include: (1) Description of the project and environmental characteristics. (2) Identification and prediction of the effect. (3) Valuation of the significance of the project's description of the project and the characteristics of the environment. The first step is based on the interaction matrix. At this stage, experts and decision makers define the project activities and the environmental components that may be affected, and then experts and decision makers each separately evaluate the environmental components in the matrix cells. And then the criteria are defined as the two profiles of interactions and environmental susceptibility (Bojo'rquez-Tapia et al., 1998).

### 2.2 Environmental factors

(1) Air pollution and micro-climate. Identification and prediction of the effects of a steel plant on the region's

climate is possible. Certain effects of certain activities, such as the use of vehicles, the construction of buildings and the increase of air outflows, can lead to climate changes, especially in the micro-clima of the factory site and around it (Monavari, 2002).

(2) Water Pollution: Physical actions such as river flow changes, causing ecological changes. Additionally, sedimentation and increase of sediment in the river, causes the flow of water to flow and reduces its depth. The drainage of water in the waters also affects the fish, with its cumulative affects significant (Monavari, 2002).

(3) Sound Pollution: The noise in the construction stages and possibly exploitation will be more than the current level. Linear noise sources can include traffic and vehicle traffic for entering and leaving the area and its perimeter. Therefore, local residents will be disturbed due to increased noise that results in noise pollution. (Monavari, 2002).

(4) Biodiversity: The cutting of plants for purification or fuel consumption is another activity that is usually carried out in the construction phase. Reducing vegetation causes changes in human and animal populations and causes many of them to emigrate. Animal species are also lost due to the loss of their habitat or the inevitable emergence of new habitats and shelters that can find their ecological conditions.

(5) Economic, social and cultural environment: Economic, social at constructional stages are exploited or are undergoing changes. Air pollution caused by project activity can affect the population of the region. The deployment of the project is likely to attract a large population. Ultimately, the decline or increase in population will affect the local economy. Cultural environments can cause serious damage to the project. Tourist and recreational centers, ancient monuments, historical, cultural and religious monuments are especially among the first places where the project activity produces harmful effects (Monavari, 2002).

**2.3 Evaluation and weighting of mathematical matrix criteria**

After weighting and valuing for each of the main and complementary criteria by experts, the importance of mutual effects was assessed by a series basic index and supplementary index. The intensity of interaction between project activities and environmental components was evaluated using seven major criteria, magnitude and duration of effect, more effects, cumulative effects and differences of opinion, as well as the criterion of compensation effect.

2.3.1 Calculation of basic criteria

Basic criteria include magnitude, extension and duration of effect. First, the experts used the matrix base scores for each of the three options, and finally, applying the researcher's opinion and analyzing expert opinions, the final weight was applied to the matrices.

Basic criteria are essential for defining interactions. While the complementary criteria are the criteria that complete these descriptions, they cannot described in the description of the effects. Scoring is based on the scaling scale from 1 to 9 (Banai-Kashani, 1989; Zhang, 2019).

From these two profiles (base and complementary), the quantitative effect between the two variables i and j can be estimated. The variables i and j represent, respectively, the environmental components and the activities of the project.

Equation (1):

$$MED_{ij} = {}^{1}/_{27}\left(M_{ij} + E_{ij} + D_{ij}\right)$$

In these equations: the magnitude of the effects; the extent of the effects; the duration of the effects; the components of the environment, and the activities of the project are included (Bojórquez-Tapia et al., 1998; Mussa, 2018).

2.3.2 Calculation of complementary criteria

Complementary criteria include the combined effects of synergy, cumulative effects and controversythat there is about the effects. Scores are considered for each of the complementary criteria in the range of 1 to 9.

Equation (2): $SAC_{ij} = {}^{1}/_{27}\left(S_{ij} + A_{ij} + C_{ij}\right)$

In these equation: $S_{ij}$: more effects; $A_{ij}$: cumulative effects; $C_{ij}$ : disagreements; $i$ : environmental components; $j$ : project activities (Bojórquez-Tapia et al., 1998; Mussa, 2018).

2.3.3 Calculation of interactions between project activity and environmental components ($I_{ij}$)

After calculating the baseline and complementary criteria, the results were included in the studies of Bukhorkoes Tapia et al. In Equation (3-3) and their results were used to calculate the significant effects.

2.3.4 Calculate meaningful effects

In this stage, the results of complementary criteria, basal measures, interactions and compensatory effects were used to calculate meaningful effects according to the studies of Bukhorvoes Tapia et al. in the following equation.

Equation (3):

$$\emptyset = 1 - SAC_{ij}^{I}$$

Equation (4):

$$I_{ij} = MED_{ij}^{\emptyset}$$

$G_{ij}$: Significance level, $T_{ij}$: Compensation factor, $I_{ij}$: Effective interaction between project activity and environmental components.

2.3.5 Calculation of Compensation Profile: This equation is used to obtain meaningful effects.

Equation (5):

$$G_{ij} = I_{ij}.\left[1 - \left(\frac{T_{ij}}{9}\right)\right]$$

Equation (6): $F_{ij} = 1 - T_{ij}/9$

Finally, we divide the effects into four groups (Bojórquez-Tapia et al., 1998): The Little effect (0.0-0.24), Moderate effect (0.25-0.49), Great effect (0.50-0.74), high effect (1- 0.75). Based on the above division, the final conclusion is made.

**2.4 Fuzzification of mathematical matrix**

MATLAB software has been used to fuzzyficate the matrix data. First, the fuzzy value of the basic and the supplementary criteria of (MEDij) and (SACij) obtained from the mathematical matrix are determined in a triangular diagram using the minimal operator. The intersection point of these two values shows their importance degree of the impact. Then, the total importance degree of the activities impacts is obtained by summing the impacts for each option. Figs 2, 3 and 4 show some examples of the graphs used in fuzzification.

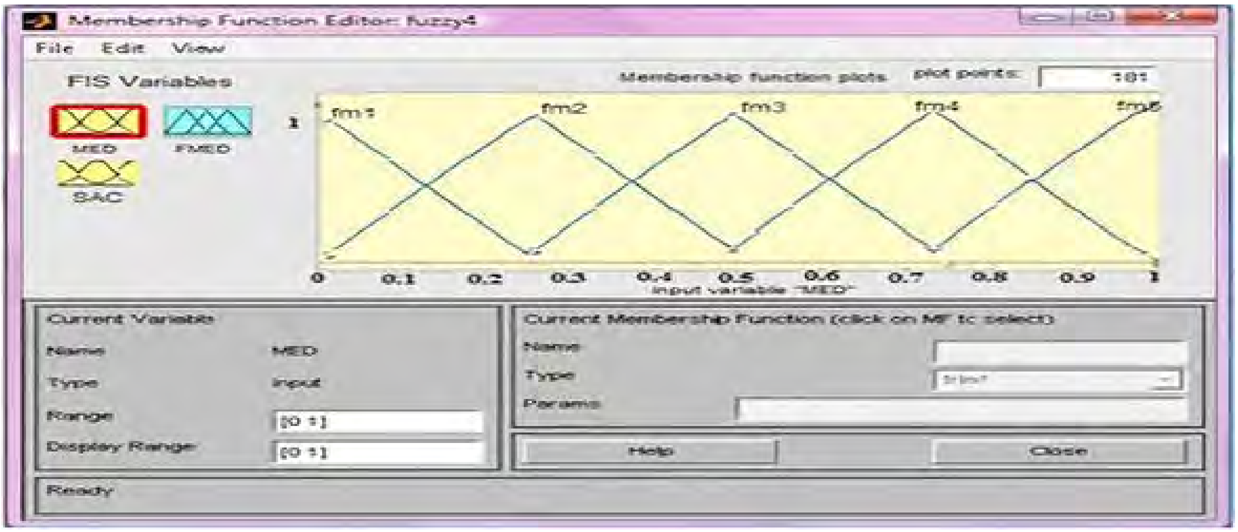


**Fig. 2** Fuzzy graph for fuzzification of (MEDij) and (SACij) criteria.


**Fig. 3** The rules which are used to fuzzyficate (MEDij) and (SACij) criteria.

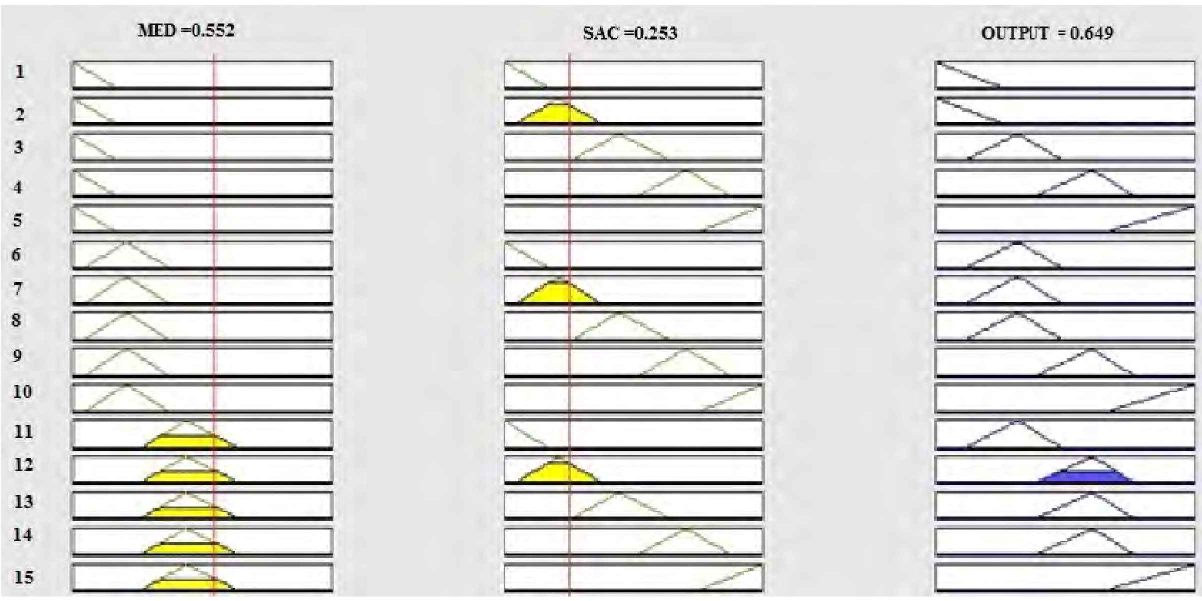


**Fig. 4** The rules which are used for a fuzzy combination of the (MEDij) and (SACij) criteria.

After the fuzzification of basic and supplementary criteria of (SACij) and (MEDij) without involving the compensating factor, it has been calculated by including the compensating factor. In order to achieve this goal, after obtaining the basic and supplementary compensation of (kij,bij), the fuzzy value of each option has been determined in the triangular diagram using a minimal operator, in the first place. The fuzzy value of the importance degree of the impact is obtained after the intersection of the two values. Then the total importance degree of the activities impacts is obtained by summing the impacts for each option. Finally, the impacts are divided into four categories, and the results have been obtained based on these divisions: low impact (0-0.24), middle impact (0.25-0.49), high impact (0.5-0.74), very high impact (0.75-1).

## 3 Conclusion

The results of this research in this section are presented below after reviewing and applying the opinions of experts in project evaluation.

### 3.1 Calculate basic index

The results of calculating the basic index (magnitude, extent, and duration of effect) according to the experts' opinions for the project are presented in the following tables, respectively. These results are obtained using equation (1).

**Table 1** Results of calculating basic index (MED).

| ActivitiesParameters | Excavator | Leveling | Building a way | Transportation | Waste and waste disposal |
|---|---|---|---|---|---|
| Air pollution and microclimate | *0.70* | *0.33* | *0.48* | *0.44* | *0.29* |
| water pollution | *0.14* | *0.03* | *0.14* | *0.07* | *0.74* |
| Soil erosion | *0.66* | *0.37* | *0.33* | *0.22* | *0.44* |
| Noise pollution | *0.33* | *0.37* | *0.48* | *0.48* | *0.03* |
| Ground deformation | *00.7* | *0.29* | *0.55* | *0.18* | *0.44* |
| Habitat destruction | *0.51* | *0.25* | *0.59* | *0.22* | *0.48* |
| Reduce biodiversity | *0.25* | *0.18* | *0.51* | *0.51* | *0.40* |
| Public health threat | *0.14* | *0.14* | *0.11* | *0.22* | *0.62* |

### 3.2 Calculation of complementary criteria

In order to calculate the complementary criteria, due to effects of synergy between the variables, the cumulative effects and controversy of the scores were taken according to the conditions of the region and compared to the project activities and environmental components, these results are obtained using equation (2). And is presented in the table below.

**Table 2** Results from Calculating Supplementary Criteria (SAC).

| ActivitiesParameters | Excavator | Leveling | Building a way | Transportation | Waste and waste disposal |
|---|---|---|---|---|---|
| Air pollution and microclimate | *0.11* | *0.11* | *0.14* | *0.18* | *0.07* |
| water pollution | *0.14* | *0.14* | *0.11* | *0.11* | *0.11* |

| | | | | | |
|---|---|---|---|---|---|
| Soil erosion | *0.11* | *0.11* | *0.07* | *0.14* | *0.07* |
| Noise pollution | *0.11* | *0.11* | *0.11* | *0.11* | *0.07* |
| Ground deformation | *0.11* | *0.11* | *0.11* | *0.07* | *0.14* |
| Habitat destruction | *00.4* | *0.07* | *0.25* | *0.07* | *0.07* |
| Reduce biodiversity | *0.11* | *0.07* | *0.59* | *0.11* | *0.07* |
| Public health | *0.07* | *0.07* | *0.11* | *0.07* | *00.4* |

### 3.3 Calculation of the effect of project activity on the environmental components ($I_{ij}$)

To calculate the impact of project activities on the environmental components, first we obtain the value of φ from equation (3) and apply the result in Equation (4). The results obtained for the project activity on the environmental components are presented in Table 3.

**Table 3** Calculation of the effect of project activity on the environmental components ($I_{ij}$).

| ActivitiesParameters | Excavator | Leveling | Building a way | Transportation | Waste and waste disposal |
|---|---|---|---|---|---|
| Air pollution and microclimate | *0.73* | *0.37* | *0.53* | *0.51* | *0.32* |
| water pollution | *0.19* | *0.06* | *0.18* | *0.09* | *0.76* |
| Soil erosion | *0.69* | *0.41* | *0.36* | *70.2* | *0.47* |
| Noise pollution | *0.37* | *0.41* | *0.52* | *0.52* | *0.04* |
| Ground deformation | *0.73* | *0.33* | *0.59* | *0.20* | *0.50* |
| Habitat destruction | *0.67* | *0.28* | *0.67* | *0.24* | *0.50* |
| Reduce biodiversity | *00.3* | *0.20* | *0.76* | *0.55* | *0.43* |
| Public health | *0.17* | *0.17* | *0.14* | *0.24* | *0.76* |

The Effect of effect Compensating factor on the Mathematical Matrix In the Mathematical Matrix, the effect compensating factor ($T_{\text{ij}}$) is used to reduce or eliminate negative effects and increase positive effects. This factor represents the compensatory activity that is being undertaken in the industry to reduce the effects of project activity $T_{\text{ij}}$, Considering the destructive effects and the consideration of the conditions of each region, they were rated in the interval from 1 to 9 (Salehi et al., 2012). The result of this scoring was laid out in the formula of calculating meaningful effects (Equivalent 5).

### 3.4 Calculate meaningful effects

The results of calculating the effect of project activity on environmental components ($I_{ij}$) as well as the effect factor compensation were used to achieve significant effects. The meaningful calculation of the effects was carried out using Equation (5) and the results are presented in Tables (4).

Results of meaningful effects in 4 categories: L: Low - M: Medium - H: High - VH: Very high.

The results of this categorization are presented in Table 5 and 6. To illustrate the importance of the factor of the significant division of the effects, the effects are shown in two tables, in Table 5, the partition is without compensation factor, and Table (6) is corrected by applying the factor.

**Table 4** Results from the significant calculation of effects ($G_{ij}$).

| Activities / Parameters | Excavator | Leveling | Building a way | Transportation | Waste and waste disposal |
|---|---|---|---|---|---|
| Air pollution and microclimate | *0.24* | *0.12* | *0.41* | *0.22* | *0.10* |
| water pollution | *0.15* | *0.04* | *0.14* | *0.08* | *0.34* |
| Soil erosion | *00.3* | *0.27* | *0.24* | *0.24* | *0.41* |
| Noise pollution | *0.25* | *0.27* | *0.46* | *0.46* | *0.04* |
| Ground deformation | *0.56* | *0.26* | *0.46* | *0.18* | *0.22* |
| Habitat destruction | *0.30* | *0.19* | *0.30* | *0.16* | *0.22* |
| Reduce biodiversity | *0.13* | *0.13* | *0.34* | *00.3* | *0.33* |
| Public health | *0.09* | *0.09* | *0.11* | *0.19* | *0.25* |

**Table 5** Results of the classification without the effect of the compensation factor.

| Total effects | Disposal of waste and waste | Transportation of materials | Construction of the main and secondary routes | Leveling and squaring | Embankment and excavator | Division of effects | |
|---|---|---|---|---|---|---|---|
| *12* | *1* | *4* | *2* | *3* | *2* | *0 - 0.24* | L |
| *12* | *3* | *1* | *1* | *5* | *2* | *0.25 - 0.49* | M |
| *13* | *2* | *3* | *4* | *0* | *4* | *0.50 – 0.74* | H |
| *3* | *2* | *0* | *1* | *0* | *0* | *0.75 - 1* | VH |

**Table 6** Results of the Classification with the effect of compensation factor.

| Total effects | Disposal of waste and waste | Transportation of materials | Construction of the main and secondary routes | Leveling and squaring | Embankment and excavator | Division of effects | |
|---|---|---|---|---|---|---|---|
| *23* | *4* | *6* | *3* | *5* | *5* | *0 - 0.24* | L |
| *16* | *4* | *2* | *5* | *3* | *2* | *0.25 - 0.49* | M |
| *1* | *0* | *0* | *0* | *0* | *1* | *0.50 – 0.74* | H |
| *0* | *0* | *0* | *0* | *0* | *0* | *0.75 - 1* | VH |

### 3.5 Fuzzification results

After calculating the supplementary and basic criteria of (SACij) and (MEDij), the fuzzy value of each project activity's impact on the environmental parameters is calculated. After the fuzzification, the two factors are combined using (AND) operator in order to calculate the impact importance degree.

**Table 7** Results of fuzzy integration without involving the compensating factor.

| ActivitiesParameters | Excavator | Leveling | Building a way | Transportation | Waste and waste disposal |
|---|---|---|---|---|---|
| Air pollution and microclimate | *0.87* | *0.56* | *0.68* | *0.68* | *0.29* |
| water pollution | *0.33* | *0.17* | *0.33* | *0.29* | *0.74* |
| Soil erosion | *0.86* | *0.63* | *0.46* | *0.41* | *0.44* |
| Noise pollution | *0.56* | *0.63* | *0.64* | *0.64* | *0.03* |
| Ground deformation | *0.87* | *0.55* | *0.76* | *0.41* | *0.44* |
| Habitat destruction | *0.67* | *0.40* | *0.88* | *0.41* | *0.48* |
| Reduce biodiversity | *0.40* | *0.41* | *0.67* | *0.63* | *0.40* |
| Public healththreat | *0.33* | *0.33* | *0.30* | *0.41* | *0.62* |

**Table 8** Results of the fuzzyfication by including the compensating factor.

| ActivitiesParameters | Excavator | Leveling | Building a way | Transportation | Waste and waste disposal |
|---|---|---|---|---|---|
| Air pollution and microclimate | *0.39* | *0.30* | *0.23* | *0.17* | *0.07* |
| water pollution | *0.30* | *0.16* | *0.30* | *0.24* | *0.31* |
| Soil erosion | *0.39* | *0.14* | *0.40* | *0.41* | *0.54* |
| Noise pollution | *0.42* | *0.41* | *0.67* | *0.39* | *0.41* |
| Ground deformation | *0.75* | *0.41* | *0.67* | *0.39* | *0.41* |
| Habitat destruction | *0.41* | *0.40* | *0.41* | *0.40* | *0.40* |
| Reduce biodiversity | *0.30* | *0.30* | *0.41* | *0.40* | *0.40* |
| Public healththreat | *0.30* | *0.30* | *0.30* | *0.09* | *0.41* |

**3.6** The results of the fuzzyfication by including the compensating factor

At this stage, the compensating factor is included and applied in both supplementary and basic criteria of (SACij) and (MEDij). The results are illustrated as a basic and supplementary compensating factor of (bij) and (kij). After obtaining the indicators (kij,bij), the numbers will enter to the fuzzy charts like the previous ones. Then, the triangular diagrams and (AND) fuzzy operator are used in the fuzzy combination. The reason for using the operator is that it considers at least two of the values of the two sets of variables; therefore, the risk will be lower.

**Table 9** Results of classifying without involving the compensating factor.

| Total effects | Disposal of waste and waste | Transportation of materials | Construction of the main and secondary routes | Leveling and squaring | Embankment and excavator | Division of effects | |
|---|---|---|---|---|---|---|---|
| *2* | *1* | *0* | *0* | *1* | *0* | *0 - 0.24* | L |
| *15* | *1* | *5* | *3* | *3* | *3* | *0.25 - 0.49* | M |
| *16* | *4* | *3* | *3* | *4* | *2* | *0.50 – 0.74* | H |
| *7* | *2* | *0* | *2* | *0* | *3* | *0.75 - 1* | VH |

**Table 10** Results of classifying with involving the compensating factor.

| Total effects | Disposal of waste and waste | Transportation of materials | Construction of the main and secondary routes | Leveling and squaring | Embankment and excavator | Division of effects | |
|---|---|---|---|---|---|---|---|
| *7* | *1* | *3* | *1* | *2* | *0* | *0 - 0.24* | L |
| *29* | *6* | *5* | *5* | *6* | *7* | *0.25 - 0.49* | M |
| *4* | *1* | *0* | *2* | *0* | *1* | *0.50 – 0.74* | H |
| *0* | *0* | *0* | *0* | *0* | *0* | *0.75 - 1* | VH |

## 4 Results and Discussion

Environmental assessment can be considered as a mechanism that reduces costs by providing correct and logical ways to use human and natural resources. This approach also has significant effects on short-term and long-term planning. Public awareness will also increase as the environmental assessment is associated with the planning process. Project executives are also able to reduce costs within the set schedule. As a result, the pressure on government funding is diminished. On the other hand, environmental assessment is leading to conserve the resources. It also prevents irreversible impacts on the environment and natural resources.

The results of this study show the difference in considering the impact of compensating factors. In many cases, the negative impacts of the industry are avoidable. The proceedings such as developing a proper drainage network to prevent leakage and infiltration into the soil and groundwater, using biofilters, regular ventilation and aeration to prevent the creation of anaerobic conditions and odor distribution and tree planting around the factories and alternative areas are reducing the negative effects of the projects. In the mathematical matrix, the results of meaningful impacts are divided into four categories: low, middle, high, and very high. The low and middle classes have some impacts on the environment, and high, and very high classes have a small share in the impact by including the compensating factor. As a matter of fact, very high class includes none of the project activities. It can be understand that the negative impacts on the environment are reduced by including the compensating factor, and the project is approved with modification proceeding. On the other hand, the results show (Table 11) that for basic factors, the highest impacts are related to the middle and low classes. For the supplementary factors, the greatest interactions are related to the low impacts.

**Table 11** The degree of the mutual impacts.

| Factor Effects | Low Effects (L) | Medium Effects (M) | High Effects (H) | Very High Effects (VH) |
|---|---|---|---|---|
| (Basic) | *13* | *17* | *10* | *0* |
| (Supplementary) | *36* | *3* | *1* | *0* |

After the fuzzification, the results show that if the compensating factor is not applied, the maximum impacts will be in the middle and high classes. Then, if the compensatory factor is applied, the impacts will be 0.73 in the middle class, and the very large class will have a small share.

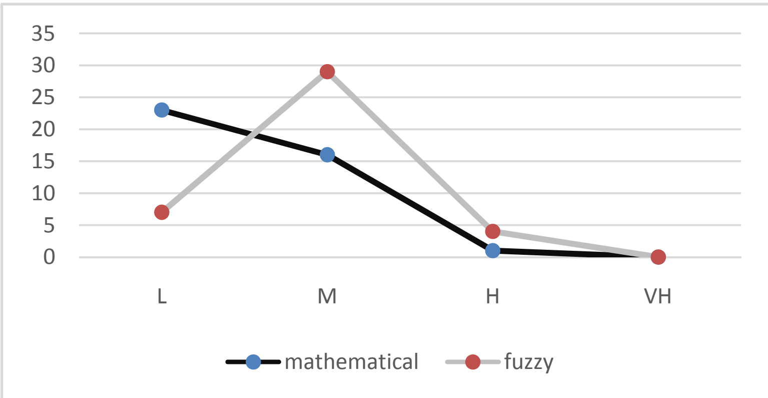


**Fig. 5** Fuzzy and mathematical comparison without involving the compensating factor.

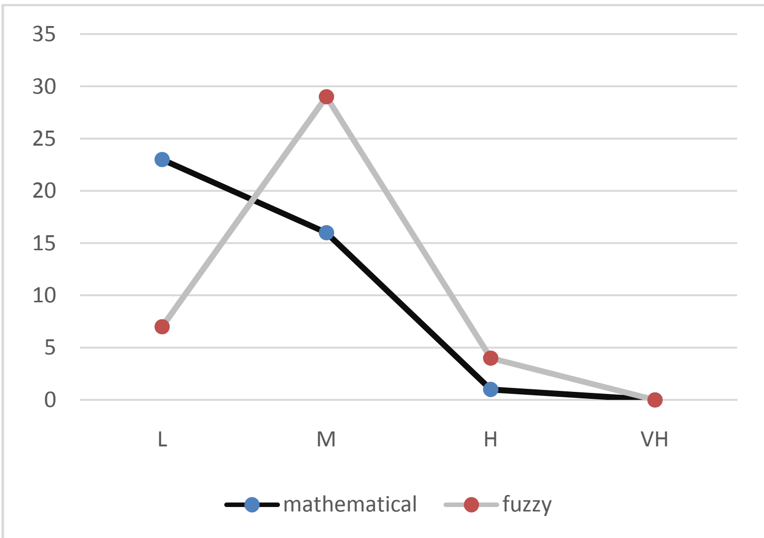


**Fig. 6** Fuzzy and mathematical comparison by including the compensating factor.

Fig. 5 and 6 demonstrate that without involving the compensating factor, most of the impacts occurred in the middle and high classes. However, by including the compensating factor, the impacts occurred in the very high class almost reaches the zero value, and most of the impacts belong to the middle class.

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