Application of Fuzzy Logic in Environmental Impact Assessment Modeling of a man-made Lake in Western Tehran (Iran)

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Abstract—Environmental impact assessment essentially depends on diverse closely connected components and variables. For this purpose, identification of the whole components is fundamentally required. This study aims to investigate environmental impact assessment of an urban man-made lake in the western part of Tehran, based on recognition of affecting components and their reciprocal effects. Since the components are not constant during the time, thus throughout the environmental impact assessment modeling study, dynamism of the relation between the components should be considered. Regarding insufficiency and uncertainty of information, an analytical method, based on expert’s opinion can be applied. For this purpose, Fuzzy group poll will be carried out throughout model structure design. In fact, in order to solve the lack of historical data in the environmental impact assessment modeling required data will be received based on group poll along with fuzzy logic and then expertise’s opinion will be methodically studied. In this research, Fuzzy Logic is applied to environmental impact assessment modeling of a man-made lake in western Tehran. Firstly, affecting and affected components have been studied using impacts matrix, then using fuzzy logic, related data required to be determined by experts on the basis of three indices such as influence rate, influence time and influence frequency. Also, all the collected responses are based on fuzzy Logic as the components of transformation function. Finally, the total results will be totalized and fuzzy quantities related to expert’s opinion can be calculated.

Keywords: Fuzzy quantity, affecting components, affected components, reciprocal effects, group poll

I. INTRODUCTION

Over the years, people believed that system’s modeling can not be practically possible by means of uncertain information. Consistently, people used to apply verbal quantities such as very, few, very very, etc. to present their real sense or special conditions whereas, in mathematical world certain quantity was attempted to be used due to Aristotle’ logic which was investigated in 1965 and 1968. Finally all these attempts resulted in a new pattern in mathematic namely “FUZZY LOGIC is “ which highly applicable, worldwide. Since there are different kinds of components in environmental impact assessment and also the EIA modeling process is carried out based on historical data, therefore, the relation between the components and dynamic models are identified on the basis of this data. Thus, in the case of decision-making according to available information, modeling based on historical data can be considered as a suitable procedure. Whereas, in the case of lack of sufficient information about components and their relations; such as environment impact assessment of a man-made lake, historical data are not suggested to be applied.

Decision-making will not be practical by unstable model structure and unknown components. Therefore, with respect to dynamic model, the EIA requires special procedures to identify the affecting and affected components and their relation. But according to experts, this model cannot be exerted as a suitable one due to the following reasons:

1) It is not possible to collect accurate data about experts’ opinions which are basically uncertain and on the basis of verbal quantity.
2) Since entire consensus among experts is not possible, therefore, any special object cannot be achieved.

II. IDENTIFICATION OF RECIPROCAL EFFECTS BETWEEN COMPONENTS

In order to indicate the model’s structure, dynamic modeling throughout environmental assessment requires considerable information about the relation between the components. Different available methodologies such as Delphi model, Nominal Group Technique, system’s analysis procedures, etc. can be applied to identify the affecting components, whereas they have not any effect on modeling and only can be considered as system components identification tools.

To indicate the relation between the components, firstly it should be specified that which components have dynamic relation (Table 1) shows the reciprocal effects of the model’s components.

<table>
<thead>
<tr>
<th>E₁</th>
<th>E₂</th>
<th>…</th>
<th>Eᵢ</th>
<th>…</th>
<th>Eₙ</th>
</tr>
</thead>
<tbody>
<tr>
<td>E₁</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E₂</td>
<td></td>
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<td></td>
<td></td>
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<td>---</td>
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<tr>
<td>Eᵢ</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Iᵢ</td>
</tr>
</tbody>
</table>
asked from all the experts and the received responses are
the opinion as verbal quantities and inaccurate data which
time and influence frequency), respectively.

In the above Table, \( i_j \) can be equal to 0 and 1,
representing lack and presence of relation between
components, respectively.

III. RESULTS

A. Application of Fuzzy Logic in data reception

Due to lack of accurate information, Fuzzy Logic is
basically applied in modeling, in order to receive required
data. In the next step, Fuzzy Logic is used to identify the
impact of affecting components \((E_i)\) on affected components
\((E_j)\). For this purpose, it is essentially required to collect
data related to influence rate, influence time and influence
frequency from experts by means of the following questions:

1) How much is the influence rate of \( E_i \) on \( E_j \)?
2) How much is the influence time of \( E_i \) on \( E_j \)?
3) How much is the influence frequency of \( E_i \) on \( E_j \)?

Throughout uncertain condition, it is suggested to collect
the opinion as verbal quantities and inaccurate data which
the related responses are based on Fuzzy Logic used as
transformation function in modeling 9.

In fact, the relation between the components will be
asked from all the experts and the received responses are
shown in (Table 2) 4.

<table>
<thead>
<tr>
<th>Respondent</th>
<th>Affecting component</th>
<th>Affected component</th>
<th>Influence rate</th>
<th>Influence time</th>
<th>Influence frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n )</td>
<td>( P_i )</td>
<td>( E_i )</td>
<td>( E_j )</td>
<td>( K_i )</td>
<td>( a_i )</td>
</tr>
</tbody>
</table>

Where, \( P_i \) = respondent (expert) code

\( E_i \) = affecting component

\( E_j \) = affected component

\( K_i, a_i, b_i \) are the triple affecting components (influence rate, influence time and influence frequency), respectively.

IV. INTEGRATION OF RECEIVED DATA

For modeling, expert’s opinion is required to be
integrated and totalized as a unit opinion 15. (Table 3) depicts
the reciprocal effects of the system’s components as a group
3.

<table>
<thead>
<tr>
<th>Respondent</th>
<th>Affecting component</th>
<th>Affected component</th>
<th>Influence rate</th>
<th>Influence time</th>
<th>Influence frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n )</td>
<td>( P_i )</td>
<td>( E_i )</td>
<td>( D_i )</td>
<td>( K_i )</td>
<td>( a_i )</td>
</tr>
</tbody>
</table>

Calculating the total experts’ opinions, in fact respondent
column can be removed, and then a Fuzzy quantity due to
total calculation of expert opinion’s verbal quantity will be
recorded in \( k, a \) and \( b \) columns 4.

V. FUZZY QUANTITY CALCULATION

In order to calculate the experts’ opinion in the case of
inaccurate information, it is recommended to apply the
Fuzzy Logic. For this purpose, the following source is
applicable 3:

\[
U = \{x_1, x_2, \ldots, x_n\}
\]

In this study, in order to identify the relation between \( I \)
and \( J \) components, shown in (Fig. 1), a group of experts
will be asked about this relation.

![Figure 1. Relation between two components](image)

If based on hypothesis, \( m \) experts have stated their
personal opinions as Fuzzy quantity about one parameter of
\( G(S) \) 3:

\[
V_1 = \{\mu_{11}/x_1, \mu_{12}/x_2, \ldots, \mu_{1n}/x_n\}
\]

\[
V_2 = \{\mu_{21}/x_1, \mu_{22}/x_2, \ldots, \mu_{2n}/x_n\}
\]

Total member function of each components of \( U \) can be
calculated as below 4:

\[
m \mu_{ij} = 1/m \sum_{i=1}^{m} \mu_{ij}
\]

Then, Fuzzy total quantity of parameter is defined as follow:

\[
V_F = \{\mu_{F1}/x_1, \mu_{F2}/x_2, \ldots, \mu_{Fn}/x_n\}
\]

Where, \( \mu_{Fj} \) is the expert’s total opinion about \( X_j \)
membership in \( V_F \) Fuzzy quantity of the relation among two
components.

VI. DEFUZZIFICATION

After using the Fuzzy group decision-making system, it
should change the above complex to defuzzification quantity
by the following equation namely Center of Gravity 20.
Where, \( Z' \) is a defuzzification quantity.

Identification of reciprocal effects throughout
Environmental Impact Assessment of man-made lake

Firstly using 0 and 1 matrix, reciprocal effects among
components are shown throughout both construction and
exploitation phases of man-made lake in western Tehran 19.
The entire components classified in two affecting and
affected groups, can be equal 0 and 1 for the case of with and without effect on each other, respectively. Matrix 1 shows a portion of components effect matrix throughout construction of a man-made lake.

TABLE 3. MATRIX FOR THE IDENTIFICATION OF RECIPROCAL EFFECTS AMONG COMPONENTS

<table>
<thead>
<tr>
<th>Effects matrix</th>
<th>Vegetation cover</th>
<th>Wildlife traffic</th>
<th>Wildlife Ecologies</th>
<th>Ecosystems</th>
<th>Protected area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemisphere</td>
<td>1 1 1 1 1 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface water quantity</td>
<td>1 1 1 1 1 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsurface water quantity</td>
<td>0 0 0 0 0 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td>1 0 1 1 1 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil erosion</td>
<td>1 0 1 1 1 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earth shape</td>
<td>- - - - - -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 4. COLLECTED GROUP DATA ABOUT RECIPROCAL EFFECTS OF TRIPLE COMPONENTS IN THE EIA

<table>
<thead>
<tr>
<th>Influence frequency</th>
<th>Delay</th>
<th>Impact</th>
<th>Triple effects</th>
<th>Affected component</th>
</tr>
</thead>
<tbody>
<tr>
<td>very</td>
<td>mean</td>
<td>low</td>
<td>zero</td>
<td>Vegetation cover</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>very</td>
<td>low</td>
<td>Wildlife traffic</td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>low</td>
<td>very low</td>
<td>Wildlife Ecologies</td>
</tr>
<tr>
<td></td>
<td>low</td>
<td>very</td>
<td>low</td>
<td>Ecosystems</td>
</tr>
<tr>
<td></td>
<td>very</td>
<td>mean</td>
<td>low</td>
<td>Protected area</td>
</tr>
</tbody>
</table>

As shown in above Table, all the responses are on the basis of verbal data, in order to receive the opinion even in uncertain condition. Therefore, total expert’s opinions are presented based on the impact of affecting component (hemisphere) on affected components (vegetation cover, wildlife,...) which results in total transformation function.

TABLE 5. GROUP DATA ABOUT RECIPROCAL EFFECTS OF SYSTEM’S COMPONENTS

<table>
<thead>
<tr>
<th>Respondent</th>
<th>Affecting component</th>
<th>Affected component</th>
<th>Influence rate</th>
<th>Influence time</th>
<th>Influence frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Xₙ₁</td>
<td>X₁</td>
<td>m</td>
<td>M</td>
<td>Nv</td>
</tr>
<tr>
<td>2</td>
<td>X₁</td>
<td>X₂</td>
<td>m</td>
<td>M</td>
<td>Nv</td>
</tr>
<tr>
<td>3</td>
<td>Xₙₓ₁</td>
<td>X₂</td>
<td>m</td>
<td>Nv</td>
<td>Nv</td>
</tr>
<tr>
<td>4</td>
<td>Xₙₓ₂</td>
<td>Xₙₓ₄</td>
<td>Nv</td>
<td>Nv</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Xₙ₁</td>
<td>Xₙₓ₉</td>
<td>Nv</td>
<td>Nv</td>
<td>V₀</td>
</tr>
<tr>
<td>6</td>
<td>X₁</td>
<td>Xₙₓ₉</td>
<td>Nv</td>
<td>Nv</td>
<td>V₀</td>
</tr>
</tbody>
</table>

{mv, nv, m, v, h} = {very few, few, mean, very, h}

x₁: Vegetation cover
x₂: Wildlife traffic
xₚ: Wildlife

VII. DISCUSSION AND CONCLUSION

A. Application of Fuzzy Logic to receive EIA components data

According to dynamic aspect of modeling, proper data about influence rate, influence time and influence frequency should be collected from environmental experts.

Following questions have been posed based on above-mentioned reciprocal effects matrix?

How is the influence rate of hemisphere on vegetation cover?

How is the influence time of hemisphere on vegetation cover?

How is the influence frequency of hemisphere on vegetation time?

Expert’s opinions about the relation between two components are recorded in (Table 4).

TABLE 6. FUZZY QUANTITIES OF K, A AND B COMPONENTS

<table>
<thead>
<tr>
<th>Affecting component</th>
<th>Affected component</th>
<th>Influence rate</th>
<th>Influence time</th>
<th>Influence frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>x₁</td>
<td>X₁</td>
<td>0/5</td>
<td>1</td>
<td>0/49</td>
</tr>
<tr>
<td>x₁</td>
<td>X₂</td>
<td>1/47</td>
<td>1</td>
<td>0/52</td>
</tr>
<tr>
<td>x₁</td>
<td>Xₙ₁</td>
<td>0/41</td>
<td>0</td>
<td>0/34</td>
</tr>
<tr>
<td>x₁</td>
<td>Xₙ₉</td>
<td>0/41</td>
<td>1</td>
<td>0/55</td>
</tr>
<tr>
<td>x₁</td>
<td>Xₙₙ</td>
<td>0/37</td>
<td>1</td>
<td>0/52</td>
</tr>
</tbody>
</table>

As shown in (Table 7), by indicating the relation between system’s components and using Fuzzy quantities, transform function of the impact of affecting components on affected
components (vegetation cover, wildlife traffic, wildlife,…) can be characterized

| TABLE 7. TRANSFORMATION FUNCTION OF ASSESSMENT COMPONENTS |
|------------------|------------------|------------------|------------------|------------------|------------------|
|                  | $x_1$            | $x_2$            | $x_3$            | $x_4$            | $x_5$            |
| $T_1$            | 0.05             | 0.47             | 0.41             | 0.4              | 0.37             |
| $T_2$            | $s_2^{-0.69}$    | $s_2^{-0.824}$   | $s_2^{-0.342}$   | $s_2^{-0.506}$   | $s_2^{-0.824}$   |

Regarding to frequency of components throughout the Environmental Impact Assessment which results in considerable limits in dynamic modeling, and also because of lack of sufficient information about the relation between components, it is highly required to apply a proper tool in order to identify the affecting and affected components and their relation. Thus, Fuzzy Logic can be used by experts to present their opinions verbally throughout the EIA dynamic modeling.

For this purpose, finally, a man-made lake has been selected to show the entire results of EIA dynamic modeling using expert’s opinions and Fuzzy group decision-making.

REFERENCES


