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Abstract.

Recently, neutrosophic cognitive maps and its application in decision making have become a topic of great importance for researchers and practitioners alike. In this paper, a new model PEST analysis is presented based on neutrosophic cognitive maps static analysis. The proposed framework is composed of five activities, identifying PEST factors and sub-factors, modelling interrelation among PEST factors, calculate centrality measures, factor classification, and factors ranking. A case study developed in environment analysis for a vertical farming project was presented, ranking factor based in interrelation and incorporating indeterminacy in the analysis. Further works will concentrate extending the model for incorporating scenario analysis.

Keywords: PEST, Neutrosophy, Neutrosophic Cognitive Maps, Static Analysis, Vertical Farming.

1. Introduction

PEST (Political, Economic, Social and Technological), is used to assess these four external factors in relation to business situation [1]. When environment and legal factors are included it is name PESTEL (Political, Economic, Socio-cultural, Technological, Environment and Legal) analysis [2]. PEST analysis lacks a quantitative approach to the measurement of interrelation among it factor is generally ignored. Neutrosophic sets and logic is a generalization of fuzzy set and logic based on neutrosophy [3].

Neutrosophy can handle indeterminate and inconsistent information, while fuzzy sets and intuitionistic fuzzy sets cannot describe them appropriately [4].

In this paper a new model PEST analysis based on neutrosophic cognitive maps (NCM) [5] is presented giving methodological support and the possibility of dealing with interdependence, feedback and indeterminacy. This paper is structured as follows: Section 2 reviews some important concepts about PEST analysis framework and NCM. In Section 3, a framework for PEST analysis based on NCM static analysis is presented. Section 4 shows a case study of the proposed model applied to vertical farming project environment analysis. The paper ends with conclusions and further work recommendations.

2. Preliminaries

In this section, we first provide a brief revision PEST analysis and the interdependency of its factors. We then provide a review of the foundations of NCM.

2.1 PESTEL Analysis

PEST (Political, Economic, Social and Technological), analysis is a precondition analysis with the mains function of the identification of the environment within which the company or project operates and providing data and information that will enable the organization predictions of new situations and circumstances [6, 7].

PEST analysis in the original formulation lack a quantitative approach to measurement and the analyzed factors are generally measured and evaluated independently [2].

PEST have a hierarchical structure of objective, factor and sub-factor (Figure 1).

In [2] a proposal from analysis PEST in a multicriteria environment is presented, but only interdependency among factor is analysis.

Additionally, factors and sub-factor have ambiguity, vagueness and indeterminacy in their structure.

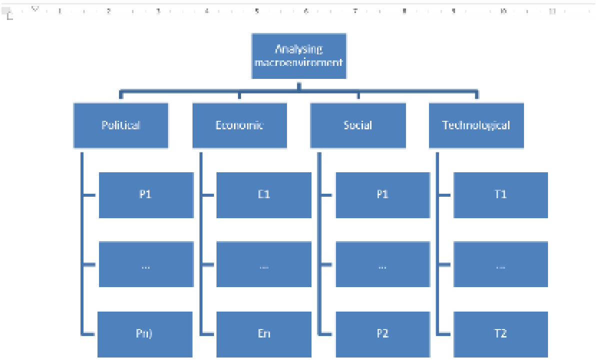


Fig. 1. The hierarchical model of PEST

This study presents a model to address problems encountered in the measurement and evaluation process of PEST analysis taking into account interdependencies among sub-factors. The integrated structure of PESTEL sub-factors were modeled by NCM and quantitative analysis is developed based on static analysis.

2.2 Neutrosophic cognitive maps

Neutrosophic Logic (NL) was introduced in 1995 as a generalization of the fuzzy logic, especially of the intuitionistic fuzzy logic [8]. A logical proposition P is characterized by three neutrosophic components:

$$NL(P) = (T, I, F) \quad (1)$$

where T is the degree of truth, F the degree of falsehood, and I the degree of indeterminacy.

A neutrosophic matrix is a matrix where the elements $a = (a_{ij})$ have been replaced by elements in $\langle R \cup I \rangle$, where $\langle R \cup I \rangle$ is the neutrosophic integer ring [9].A neutrosophic graph is a graph in which at least one edge is a neutrosophic edge [10]. If indeterminacy is introduced in cognitive mapping it is called Neutrosophic Cognitive Map (NCM) [11].

NCM are based on neutrosophic logic to represent uncertainty and indeterminacy in cognitive maps [3]. A NCM is a directed graph in which at least one edge is an indeterminacy denoted by dotted lines [12] (Figure 2.).

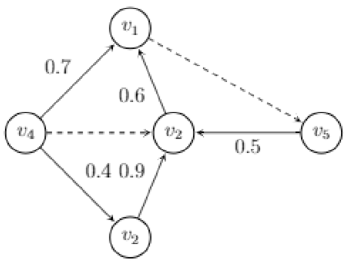


Fig. 2. Fuzzy Neutrosophic Cognitive Maps example.

In [13] a static analysis of mental model in the form of NCM is presented. The result of the static analysis result is in the form of neutrosophic numbers (a+bI, where I = indeterminacy) [14]. Finally a deneutrosophication process as proposes by Salmeron and Smarandache [15] is applied to given the final ranking value. In this paper this model is extended and detailed to deal with factor classification and prioritization.

3. Proposed Framework

Our aim is to develop a framework PEST analysis based on NCM. The model consists of the following phases (graphically, Figure 3).

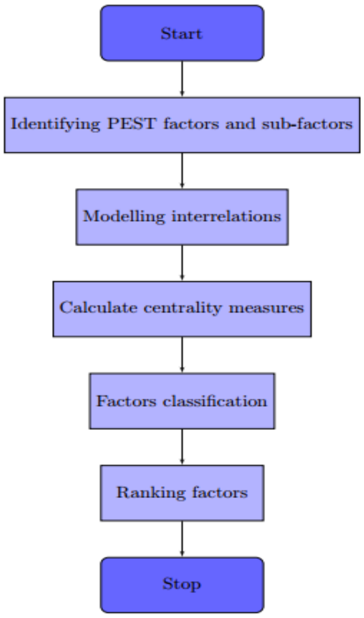


Fig. 3. Proposed framework for PEST analysis.

3.1 Identifying PEST factors and sub-factors

In this step, the relevant PESTEL factors and sub-factors are identified. PESTEL factors are derived from the themes: political, economic, socio-cultural, technological factors. Identifying PEST factors and sub-factors to form a hierarchical structure of PESTEL model (Figure 1.)

3.2 Modelling interdependencies

Causal interdependencies among PEST sub-factors are modelled. This step consists of the formation of NCM of sub-factors, according to the views of the expert team.

3.3 Calculate centrality measures

The following measures are calculated[16] with absolute values of the NCM adjacency matrix [17]:

1. Outdegree $od(v_i)$ is the row sum of absolute values of a variable in the neutrosophic adjacency matrix. It shows the cumulative strengths of connections (c_{ij}) exiting the variable.

$$od(v_i) = \sum_{i=1}^{N} c_{ij} \quad (2)$$

2. Indegree $id(v_i)$ is the column sum of absolute values of a variable. It shows the cumulative strength of variables entering the variable.

$$id(v_i) = \sum_{i=1}^{N} c_{ji} \quad (3)$$

3. The centrality (total degree $td(v_i)$), of a variable is the summation of its indegree (in-arrows) and outdegree (out-arrows)

$$td(v_i) = od(v_i) + id(v_i) \quad (4)$$

3.4 Factors classification

Factors are classified according to the following rules:

a) Transmitter variables have a positive or indeterminacy outdegree, $od(v_i)$ and zero indegree, $id(v_i)$.

b) Receiver variables have a positive indegree or indeterminacy, $id(v_i)$., and zero outdegree, $od(v_i)$.

c) Ordinary variables have both a non-zero indegree and. Ordinary variables can be more or less a receiver or transmitter variables, based on the ratio of their indegrees and outdegrees.

3.5 Ranking Factors

A de-neutrosophication process gives an interval number for centrality. This one is based on max-min values of I . A neutrosophic value is transformed in an interval with two values, the maximum and the minimum value ∈ [0,1] .

The contribution of a variable in a cognitive map can be understood by calculating its degree centrality, which shows how connected the variable is to other variables and what the cumulative strength of these connections are. The median of the extreme values [18] is used to give a centrality value :

$$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2} \quad (5)$$

Then

$$A > B \Leftrightarrow \frac{a_1 + a_2}{2} > \frac{b_1 + b_2}{2} \quad (6)$$

Finally, a ranking of variables is given. The numerical value it used for factor prioritization and/or reduction [19].

4. Case Study

Environmental concerns, including issues of ecological justice, attention to sustainability, and focus on issues of food security have gathered increased momentum in vertical farming [20]. This case study is based in a vertical farming project proposal at the University of Guayaquil.

In recent years, Guayaquil has become a city of cement with scarcity on green areas [21]. The main goal of the project is the optimization and use of spaces not suitable for cultivation, such as walls and terraces; with systems of supports helping in the beautification of the environment and allow the planting of plants of distinct types obtaining a commercial harmony sustained in the environment.

Initially factors and sub-factors were identified. Figure 3 shows the hierarchical structure.

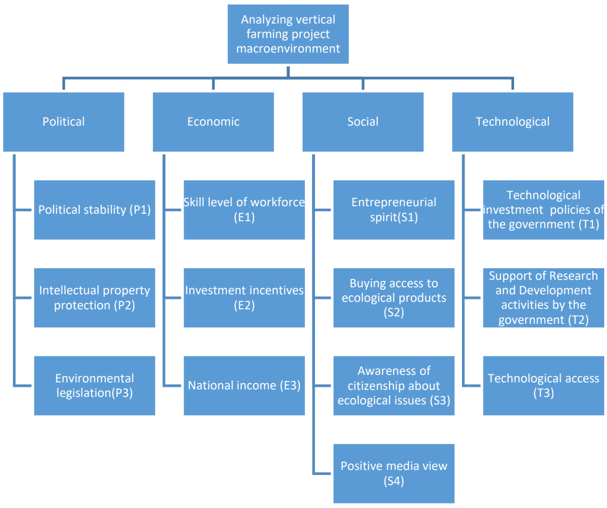


Fig. 4. The hierarchical model of PEST in the vertical farming project.

Interdependencies are identified and modelled using a NCM. NCM with weighs is represented in Table 1.

Table 1. Neutrosophic Adjacency Matrix

	P1	P2	P3	E1	E2	E3	S1	S2	S3	S4	T1	T2	T3
P1	0	0	0	0	0	0	0	0	0	0	0.7	0.6	0
P2	0	0	0	0	0.4	0	0	0	0	0	0	0	I
P3	0	0	0	0	0	0	0	0.3	0	0	0	0	0
E1	0	0	0	0	0	0	0.6	0	0	0	0	0	0
E2	0	0	0	0	0	0.3	0.4	0	0	0	0	0	0
E3	0	0	0	0	0	0	0	0.8	0	0	0	0	0
S1	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	0	0	0	0	0	0	0	0	0	0	0	0	0
S3	0	0	0	0	0	0	0	0	0	0	0	0	0
S4	0	0	0	0	0	0	0	0	0	0	0	0	0
T1	0	0	0	0.2	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	I	I	0	0.4	0.5	0	0	0
T3	0	0	0	0	0	0	0.4	0	0	0	0	0	0

The centralities measures are calculates. Outdegree and indegree measures are presentes in Table 2.

Table 2. Centrality measures, outdegree, indegree.

	id	od
P1	1.3	0
P2	0.4+I	0
P3	0.3	0
E1	0.6	0.2
E2	0.7	0.4
E3	0.8	0.3+I
S1	0	1.4+I
S2	0	1.1
S3	0	0.4
S4	0	0.5
T1	0.2	0.7
T2	0.9+2I	0.6
T3	0.4	I

Later nodes are classified. In this case, political nodes are transmitter and social nodes are received. The rest of the nodes are ordinary.

Table 3. Nodes classification

	Transmitter	Receiver	Ordinary
P1	X		
P2	X		
P3	X		
E1			X
E2			X
E3			X
S1		X	
S2		X	
S3			
S4			
T1			X
T2			X
T3			X

Total degree (Eq. 4) was calculated. Results are show in Table 5.

Table 4. Total degree

	td
P1	1.3
P2	0.4+I
P3	0.3
E1	0.8
E2	1.1
E3	1.1+I
S1	1.4+I
S2	1.1
S3	0.4
S4	0.5
T1	0.9
T2	1.5+2I
T3	0.4+I

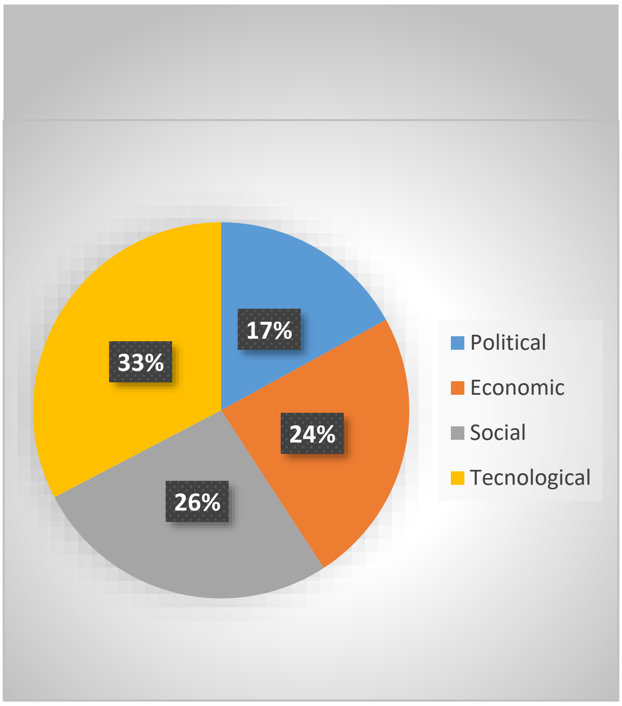
The next step is the de-neutrosophication process as proposes by Salmeron and Smarandache [15]. I ∈[0,1] is replaced by both maximum and minimum values. In Table 6 are presented as interval values.

Table 3. De-neutrosophication, total degree values

	td
P1	1.3
P2	[0.4, 1.4]
P3	0.3
E1	0.8
E2	1.1
E3	[1.1, 2.1]
S1	[1.4, 2.4]
S2	1.1
S3	0.4
S4	0.5
T1	0.9
T2	[1.5, 3.5]
T3	[0.4, 1.4]

Finally we work with the median of the extreme values (Eq 5) [18].

Table 4. Total degree using median of the extreme values



	td
P1	1.3
P2	0,9
P3	0.3
E1	0.8
E2	1.1
E3	1.6
S1	1,9
S2	1.1
S3	0.4
S4	0.5
T1	0.9
T2	2.5
T3	1.4

Graphically the result is shown in Figure 4.

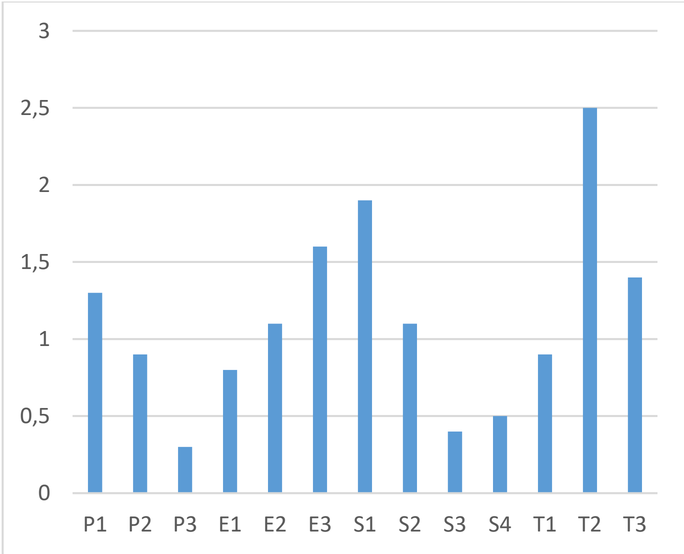


Fig. 5. Total degree measures

The ranking obtained is as follows:

$$\mathbf{T_2 \succ S_1 \succ E_3 \succ T_3 \succ P_1 \succ E_2 \sim S_2 \succ P_2 \sim T_1 \succ E_1 \succ S_4 \succ S_3 \succ P_2}$$

Support of research and development activities by the government was selected as the top environment factor at this vertical farming initiative. Centrality measures of sub factor were grouped according to its factors (Figure 6).

Fig. 6. Aggregated total centrality values by factors

After application in this case study the model is found to be practical to use. The NCM gives a high flexibility and take into account interdependencies PEST analysis

5. Conclusions

This study presents a model to address problems encountered in the measurement and evaluation process of PEST analysis taking into account interdependencies among sub-factors modeling uncertainty and indeterminacy. The integrated structure of PESTEL sub-factors were modeled by NCM and quantitative analysis is developed based on static analysis.

To demonstrate the applicability of the proposal a case study to a vertical farming project proposed at the University of Guayaquil. Most notably, this is the first study to our knowledge to integrate NCM to the PEST analysis Schema. Our approach has many applications in complex decision problem that include interdependencies among criteria, and such as complex agriculture decision support.

Further works will concentrate extending the model for dealing scenario analysis and the use of compensatory operator in static analysis [22] . Another area of future work is the developing a consensus model for NCM and the development of a software tool.

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