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# Evaluation of the Impact of Informal Trade using Neutrosophic Cognitive Maps and Weighted Power Mean Operator

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**Abstract:** The commercial relationships that are generated as part of economic development can be classified as formal or informal according to the nature of their transactions. Informal trade establishes a direct relationship with social forces. However, evaluating the impact of informal trade represents an unsolved task for science. This research proposes a solution to the posed problem by developing a method to evaluate the impact of informal trade. The proposed method consist of modeling causal relationships using Cognitive Maps and the Weighted Power Mean (WPM) operator. It models uncertainty using Neutrosophic Numbers. The proposal has been implemented in the Mariscal de Puyo market, where it was possible to quantify its impact.

**Keywords:** Cognitive Map; Neutrosophic Numbers; Informal trade; evaluation, WPM operator.

## 1. Introduction

Trade relations are established as part of economic progress. The relations make up the mercantilist societies from which the social strata are created [1, 2]. Mercantile relations implement a direct relationship with the levels of trade, with which economic transactions are carried out [3, 4]. Transactions can be executed formally or informally [5, 6].

The transactions are in correspondence with the development characteristics of the towns [7]. They are directly related to social forces: poverty, migration and unemployment [8]. Government administrations have generated legal regulations to control, order and organize informal trade [9, 10]. However, the evaluation of the impact of informal trade represents an area of knowledge that has not been sufficiently addressed.

The objective of this research is to develop a method using a Neutrosophic Cognitive Map and the WPM operator [11] to evaluate the impact of informal trade. This paper continues with section 2, which introduces some preliminary concepts. Section 3, develops the framework to evaluate the impact of informal trade. Section 4 presents the Mariscal de Puyo market study case. Paper ends with the conclusions and future works recommendations.

## 2. Preliminaries

In this section, we present the theoretical referents that characterize the problem under study. The different concepts that facilitate the understanding of the research are also discussed, along with a description of informal trade. In addition, Neutrosophic Cognitive Maps are characterized as a way to model causal relationships and Neutrosophic numbers are presented because they are capable of modeling uncertainty in decision-making problems.

## 2.1 Informal trade

The retail trade carries out informal commercial activities[12]. Retail trade on public roads is the activity of people who are engaged in the sale of products and the provision of services of various kinds [13, 14]. According to the new developments, it is necessary to evaluate the impact of informal trade on the Mariscal de Puyo market. For which three fundamental aspects were determined to carry out the evaluation: Diversification of the Informal Trade Offer, Use of Public Space and Competitive Advantages for Marketing.

Informality shows its problem from its own definition [15]. In the different studies carried out in the informal sector, it is observed that this term is often used as a synonym for a street market, without formality, without public safety or benefits. However, the most general sense is to consider the informal sector as the group of workers who do not have social security [16, 17]. They are known by various names: street vendors, artisans, unions, micro-entrepreneurs, and others.

## 2.2 Neutrosophic Cognitive Map

Fuzzy Cognitive Maps (FCM) are a tool that aims to expand the work horizon that involves the implementation of traditional cognitive maps and concept maps [18-20]. These maps, in more advanced versions, can include the combination of techniques belonging to Soft Computing [21], such as Artificial Neural Networks and Fuzzy Logic [22-24]. FCMs belong to a constantly developing area and alternatives are currently being investigated to increase the reliability of the inference process [25-27].

In the 1980s, Romanian polymath F. Smarandache founded the international movement called Paradoxism [28], based on the occurrence of contradictions in science and art, which was then extended to Neutrosophy, based on contradictions and their neutrals. This has formed the basis for a series of mathematical theories that generalize classical and fuzzy theories such as Neutrosophic sets and Neutrosophic logic [29, 30]. Neutrosophic Cognitive Maps (NCM) represent an extension of the FCM to work with neutrosophic numbers. The original definition of truth value in Neutrosophic logic is:

$$N \{(T,I,F):T,I,F \subseteq [0,1]\}$$

$n$ , in which: T, represents the degree of membership; I, the degree of indeterminacy; and F, the falsehood.

What represents a Neutrosophic evaluation, considered as a mapping of a group of propositional formulas to N, and for each sentence  $p$  to obtain the result through equation 1.

$$v(p) = (T, I, F) \quad (1)$$

The NCM theory expresses that for each connection on the map there is a weight that denotes the degree of causality. This characteristic allows to implement knowledge concerning the strength of each causal relationship [31]. Specifically, the connections in an NCM have associated a numerical value in the range [-1,1] that regulates the direction and intensity of the causal relationship between the concepts that define the system.

## 3. Framework for evaluating the impact of informal trade

This section describes the operation of the framework to evaluate the impact of informal trade using a Neutrosophic Cognitive Map. The main elements that characterize the proposed method are described below.

The method is built to assess the impact of informal trade. It is divided into three basic activities: input, inference and results. Figure 1 shows a general outline of the proposed method.

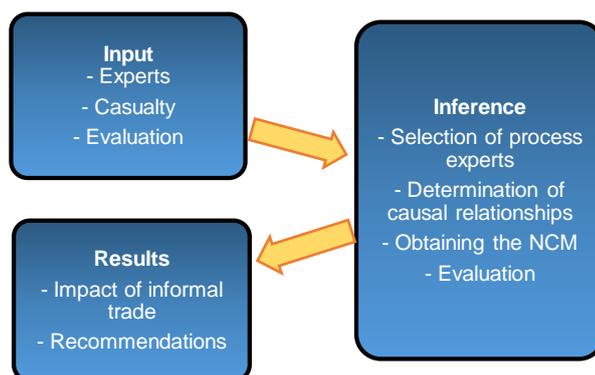


Figure 1. Structure of the proposed method.

The proposed structure for the method supports workflow management for evaluating the impact of informal trade. The method employs a multi-expert multi-criteria approach. The inference process uses data from the set of evaluation indicators proposed for the evaluation of the result.

The inference process is described using soft computing techniques with the implementation of the Neutrosophic Cognitive Map technique [32, 33]. Figure 2 shows a diagram with the activities of the method.

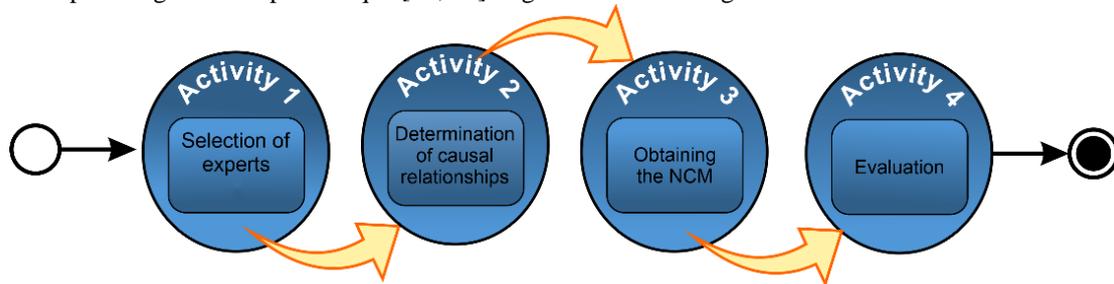


Figure 2. Method workflow activities.

Below there is a description of the proposed activities:

*Activity 1. Select the experts and determine the indicators.*

The method begins with the selection of experts and the identification of evaluation indicators. For the activity the multi-expert approach is formalized as:

The number of experts involved in the process  $E = \{e_1, \dots, e_m\}$ , mes,

The number of evaluation indicators of the process  $I = \{i_1, \dots, i_n\}$ , nes,

*Activity 2. Determinations of causal relationships*

This activity establishes the relationship of the concepts on the map. Causal relationships are expressed by fuzzy variables from linguistic terms.

During the activity, each expert expresses the relationship between each pair of indicators  $C_i$  and  $C_j$  on the map. Then, for each causal relationship,  $K$  rules are obtained with the following structure: If  $C_i$  is A then  $C_j$  is B and the weight  $W_{ij}$  is C.

Then the Centroid method and the Mamdani inference mechanism are used to add the  $k$  rules, and the de-fuzzified value is the weight of the relation.

*Activity 3 obtaining the resulting NCM:*

Once the causal relationships are identified, this knowledge is organized through the adjacency matrix [34]. The matrix represents the result of the aggregation process of information on the criteria issued by the experts. The resulting Cognitive Map has the causal relationships with the node weights [35, 36].

Static analysis is performed on the resulting knowledge that is stored in the adjacency matrix. As a result, the values of the output degree are obtained using equation (2), where the weights attributed to each manifestation are obtained based on total degree [37]. Values described below are used in the proposed model, based on the absolute values of the adjacency matrix [38]:

$$w_i = \frac{td(v_i)}{\sum_{i=1}^n td_i} \tag{2}$$

Where  $td(v_i)$  is the total degree value of the  $i$ th node

*Activity 4 evaluation*

The evaluation activity consists of the inference process carried out in accordance with the proposed method.

The aggregation function used  $OAG: [0,1]^n \rightarrow [0,1]$  is the Weighted Power Mean (WPM) using the model of Logic Scoring of Preferences (LSP) [11]. The  $r$ -th WPM is defined as follows:

$$M_n^{[r]}(\underline{a}, \underline{w}) = \left( \sum_{i=1}^n a_i^r w_i \right)^{\frac{1}{r}} \tag{3}$$

where  $w_i \in [0,1]$  and  $\sum_{i=1}^n w_i = 1$  and  $r$  could be selected to achieve the expected logic properties. puede ser seleccionadas para lograr propiedades lógicas deseadas.

#### 4. Application of the method to evaluate the impact of informal trade: Mariscal de Puyo market study case

This section describes the implementation of the proposed method. A case study is carried out where it is possible to assess the impact of informal trade. For the proposed method, a multi-criteria evaluation system is implemented. The method allows an evaluation of the impact of trade to be obtained using causally related evaluation indicators. The proposal used the Mariscal de Puyo market as a case study. Below, is a description of the process.

##### Activity 1. Select the experts and determine the indicators

For the development of the study, 7 experts were consulted who represented the basis for the identification of causal relationships. The knowledge of the indicators that impact on trade was taken into account.

From the work with the experts, 4 evaluation indicators were identified, which are shown in Table 1.

No.	Indicator
1	Crafts
2	Nutrition
3	Services
4	Health

Table 1. Evaluation indicators

The main indicators to be evaluated are conceptually defined:

- Crafts refers to the activity of selling objects and crafts made manually by people.
- Nutrition refers to the sale of food, vegetables, sweets and other products obtained from agriculture.
- The services refer to beauty activities such as hairdressing, manicures and others of this nature.
- Health services refer to chiropedic activity carried out at home and others of this nature.

##### Activity 2. Determine causal relationships

For the process of identification of the causal relationships, 7 adjacency matrices were obtained corresponding to the 7 experts who participated in the process, which were added to the resulting matrix. Table 2 shows the adjacency matrix resulting from the process.

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>
C <sub>1</sub>	0	0.25	0.25	0.2
C <sub>2</sub>	I	0	I	0
C <sub>3</sub>	0	0.5	0	0.2
C <sub>4</sub>	0.5	0	0.2	0

Table 2. Adjacency matrix of evaluation indicators

##### Activity 3. Obtaining the resulting NCM

Figure 4 shows the resulting Neutrosophic Cognitive Map using Mental Modeler Software [39]. The result obtained is a Neutrosophic Cognitive Map of the method for evaluating the impact of informal trade.

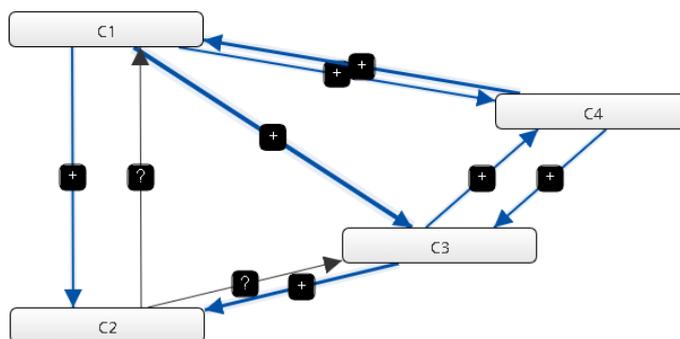


Figure 3. Neutrosophic Cognitive Map.

#### Activity 4. Evaluation

From the adjacency matrix, the weights attributed to the evaluation indicators were identified by solving equation (2). Table 3 shows the results obtained from the weights.

No.	Evaluation indicators	Weight
C1	Crafts	0.11
C2	Nutrition	0.08
C3	Services	0.10
C4	Health	0.05

**Table 3.** Weight attributed to evaluation indicators

Once the weights of the indicators have been determined. The preferences of the object of analysis are determined. The preferences are calculated according to the mean of experts' evaluation in the scale 0-1. The evaluation is carried out using WMP operator (3) with  $r=0.619$

Criteria	Weights	Preferences
C1	0.32	0.75
C2	0.23	1
C3	0.31	0.5
C4	0.14	1
Index		0.77

**Table 4.** Weight and attributed preferences for method development.

Once the evaluation of the impact of informal trade has been obtained, an analysis of the result is carried out. An evaluation index of  $I= 77$  is evident. From the result, we can conclude that the evaluation of the impact of informal trade is at a high level.

## Conclusions

From the development of the proposed research, a method for evaluating the impact of informal trade was obtained. The method operates by using a multi-expert multi-criteria approach.

During the implementation of the method, the aggregated Neutrosophic Cognitive Map was obtained with the representation of the causal relationships on the evaluation criteria that determine the impact of informal trade. The resulting Neutrosophic Cognitive Map and the WPM operator forms the basis for the inference of the operation of the proposed method.

With the application of the method in the Mariscal de Puyo market study case, it was possible to demonstrate the applicability of the method that allowed evaluating the impact of informal trade from the set of evaluation criteria. As a result, a high-level evaluation is obtained, which is considered as "Very good".

For the development of future research, the implementation of new information aggregation models that manage knowledge based on different criteria defined in the scientific literature, such as modeling uncertainty in a pessimistic or optimistic way, would be recommended.

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