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Abstract: The development of smart cities has been gaining attention not only in India but across borders. The development of these cities is supposed to bring India as a smart India in the global market. With all odds in favor; these projects are not gaining their expected on-time results. This has motivated us to think that there are loopholes that are putting hindrance to smart cities development. The aim of this study is to identify and prioritize mathematically the key barriers using the neutrosophic PESTEL analysis technique. An extensive literature survey of the problem provides a lot of factors which are categorized in six main factors such as social, political, legal, ethical and technological factors. Present work using neutrosophic PESTEL analysis finds that social and political factors with 93% and 83% are the key barriers to the development of smart cities in India. Other factors such as Technological and economic factors come at second position securing percentage 75% and 60% respectively. Environmental and legal factors come at last securing 49% and 43% respectively. The research's main focus is to identify and prioritize quantitatively the most important barriers which come into smart cities development in India. This research in many ways would aid the Government agencies and policymakers to prioritize the key barriers at an early stage so that the development may take place as expected and get completed within the stipulated time frame.

Keywords: Smart Cities, Fuzzy Logic, Fuzzy Cognitive Maps, Neutrosophic Logic, Neutrosophic Cognitive Maps, PESTEL Analysis, Machine Learning.

1. Introduction

The development of smart cities is gaining much attention all over the globe in the last 20 years [1-3]. A smart city in this context can be defined as a city with technological advancements and modernized territory. These cities are capable of dealing with issues like social, economic and technical in such a way that these could lead to superior infrastructure and services [4-8]. With the advent of information & technology together with the policies of the Indian government, these projects seem to get completed in near future. In India people are heading from rural to urbanization at faster rate. This rate is expected to expand the cities to 600 million by 2030. A study by [9] has predicted that at least 200 million people would move from rural areas to urban areas within 15 years from now. According to United Nations Population Fund (UNFPA) [10], a substantial share of population will move from rural to urban areas by 2050. This movement of population is not normal as it would lead to population nearly equal to existing populations of some prominent counties like the United Kingdom (UK), Germany and France taken together. This shift from rural areas to urban areas is how ever slow in India. According to census 2011 this is only 31.5% of total population in India. The reason behind this may be insufficient government policies together with managing the urban dynamics.

The issue of development of smart cities in India is undertaken as an initiative to improve the quality of life and providing basic necessities to its people [11-12]. However, these cities need a totally different perspective for its development in India. The need of the hour is faster development of these

cities but it is not achieved despite so much of planning and initiatives. The development of these cities generate a lot of problems which can be physical problems like pollution, resource management, traffic, digitization of data and many more [13-14]. There is also lack of strategic planning pertaining to smart cities development [15]. The projects related to smart cities in India are not getting completed at an expected time despite lot of resources and planning. Moreover these projects are taking longer to get completed without serving the objectives of the project. These loopholes in carrying out these projects have motivated us to identify barriers to the development of smart cities in India. Also, the need of these cities are getting increased at faster rate than its development in India. These reasons serve as primary cause for taking current research at present time.

The current work is grouped in following sections, Section 2 explains well the materials and methods required to understand the work carried out in present research. Section 3 of Results exposes the application of Neutrosophic PESTEL analysis in identifying the key barriers in the development of smart cities in India. This section shows how the situation is modelled in current work using various methods together with giving detailed description of results obtained. Section 4 concludes the paper with more emphasis on future work.

2. Material and Methods

Now, let us understand neutrosophy which is further combined with PESTEL analysis in the present work. Neutrosophic theory was proposed by Florentin Smarandache [18] which is popular theory for the treatment of uncertainties. It helps in generalizing crisp fuzzy sets and theories by introducing some concepts such as neutrosophic sets and neutrosophic logic [18]. When PESTEL technique is used together with neutrosophic logic it becomes neutrosophic PESTEL analysis as used in [19]. The study carried out in [19] is related to food industry where authors have tried to identify factors that affect Food Industry using this technique. The current study uses the technique of PESTEL analysis in determining the key barriers for smart cities development in India. The technique based on neutrosophic cognitive maps permits us to analyze specific topics mathematically using neutrosophic sets and systems. The approach is based on expressive technique with a quantitative strategy. Since this PESTEL analysis is combined with neutrosophy therefore it is required to understand certain concepts which are needed in order to carry out the mathematical work. For this let understand the concept of neutrosophic logic presented by Florentin Smarandache [20]. The latest developments could easily be referred from the work done in [40-44].

Definition1. Let $N = \{(T, I, F): T, I, F \in (0,1)\}$ be a neutrosophic set. Let $m: P \to N$ be a propositional relation into N, i.e., for every $p \in P$ there is association with a value in N, as mentioned in Equation 1,expressing that p is F% false, I% indeterminate and T% true.

$$m(p) = (T, I, F) \qquad (1)$$

Hence, the generalization of fuzzy logic is termed as neutrosophic logic, based on the notion of neutrosophy [18] [21]

Definition2. A Neutrosophic matrix is a matrix= $[a_{ij}]_{ij}$ where $i = 1,2,3, \ldots \ldots, m$ and $j = 1,2,3, \ldots \ldots, n$ such that each $a_{ij} \in K(I)$ where K (I) is a neutrosophic ring [22] Now let understand this neutrosophic matrix by an example. Suppose each element of matrix is represented by $a + bI$ where a and b are real numbers and I is a factor of indeterminacy.

For Example:

$$\begin{pmatrix} -1 & I & 5I \\ I & 4 & 7 \end{pmatrix} \begin{pmatrix} I & 9I & 6 \\ 0 & I & 0 \\ -4 & 7 & 5 \end{pmatrix} = \begin{pmatrix} -21I & 27I & -6 + 25I \\ -28 + I & 49 + 13I & 35 + 6I \end{pmatrix}$$

Definition 3. A graph is called a neutrosophic graph if there exists an indeterminate node or an indeterminate edge where $a_{ij} = 0$ it means there is no connection between nodes i and j, $a_{ij} = 1$ means there is a connection between nodes i and j and $a_{ij} = I$ means that connection is indeterminate (unknown).

Definition 4. A Neutrosophic Cognitive Map is a directed graph [23] with nodes as events or policies and causalities or relationship as determinate &indeterminate edges. The determinate edge or unbroken edge between two concepts shows that the relationship is certain and known whereas on the other hand the indeterminate or dotted edge between the concepts shows that the relationship is not certain or may be unknown. The below graph shows an example of neutrosophic graph in which the edge between node v_4 and v_1 is termed as determinate and edge between v_1 and v_5 is termed as indeterminate. This is represented in Figure 1.

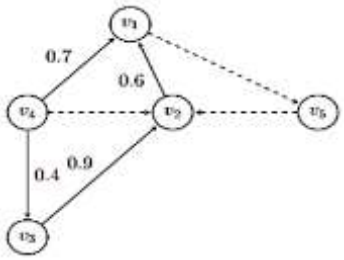

Figure 2 Example of Neutrosophic Cognitive Map

In order to include an indeterminate framework in the PESTEL analysis Neutrosophic Cognitive Maps (NCMs) are used extensively in this research. Neutrosophic Cognitive Maps (NCMs) are regarded as generalization of Fuzzy Cognitive Maps (FCMs). Fuzzy Cognitive Maps with their possible applications are well explained in [24]. The nodes in FCMs represent events or variables which are modelled to ascertain the possible relationship among them. The arcs among the nodes shows the relationship among nodes which could be positive or negative. These relationships are termed as causal where '+1' indicates the positivity and '-1' indicates the negativity of relation. Though FCMs are very much effective in modelling any situation but it lacks on certain grounds like it could not model uncertain, indeterminate and not known relations. To the rescue Neutrosophic Cognitive Maps (NCMs) are introduced in [18] [22] [31] are a way different from fuzzy cognitive maps (FCMs). FCMs do not include the notion of indeterminacy in them which is always present is neutrosophic cognitive mapping making it more efficient and accurate.

Below shown framework in Figure 2 presents a way to analyze factors for identifying and characterizing barriers to smart cities development in India with a model called PESTEL.

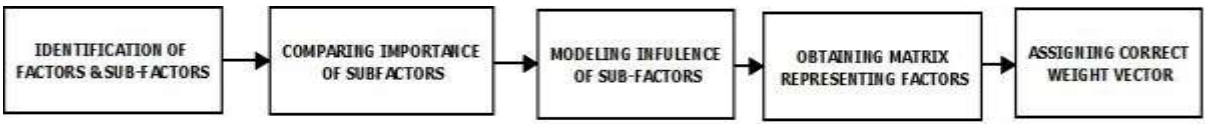

Figure 3 Framework for obtaining characteristics in every factor being analyzed by PESTEL model

The analysis using PESTEL has gained popularity since its mention in [17]. The term PESTEL was coined in the book titled "Exploring Corporate Strategy" by Johnson and Scholes. PESTEL analysis is a technique that strategically tries to identify the external environment that influences the factors such as political, economic, social, technological, environmental and legal. The factors obtained are later integrated corresponding to analysis of PESTEL and then modelled using Neutrosophic Cognitive Maps (NCMs). This modelling provides for quantitative analysis of characteristics under consideration which correspond to analysis of factors. Further a neutrosophic adjacency matrix is formulated. By

taking into consideration the adjacency matrix and their absolute weights the static analysis is applied. When it is talked about static analysis in neutrosophy or neutrosophic cognitive maps [26] the special types of numbers called neutrosophic numbers like "$a + bI$" are taken in considerations where "a" and "b" are real numbers and "I" is called indetermination [27]. This not only deals with neutrosiphication but also de- neutrosiphication. This is well proposed in [28] by Salmeron and Smarandache where $I \in (0,1)$ and takes the value which is minimum or maximum. For static analysis of factors some measures are the need of the hour. The measures which are used extensively in proposed model are described below by equations 2-6. These measures are based on the absolute values of adjacency matrix [25]. These measures are used in further calculations for PESTEL analysis. Now let understand each one by one:

Definition 5. Out-degree in any graph represents the strength of outgoing relationship of a variable. It is described as sum of all elements of a row in corresponding neutrosophic adjacency matrix. It is represented in equation numbered 2.

$$\text{Outdegree (node)} = \sum_{i=1}^{n} |c_{ij}|, \tag{2}$$

Definition 6. In-degree in any graph represents the incoming relations from a variable. It is described as sum of all column elements in corresponding neutrosophic adjacency matrix. It is represented in equation numbered 3.

$$\text{Indegree (node)} = \sum_{i=1}^{n} |c_{ij}|, \tag{3}$$

Definition 7. Total degree or total centrality can be expressed as the sum of in-degree and out-degree. Equation 4 gives its mathematical notation.

$$\text{Total Degree} = \text{Indegree (node)} + \text{Outdegree (node)}, \tag{4}$$

Finally using equations 5 and 6 the averages of extreme values is calculated which is mostly used to obtain single value used in calculation [29]. This value is used in our case study for recognition of the features or characteristics.

$$\partial([a, b]) = \frac{a+b}{2}, \tag{5}$$

Then,

$$A > B \leftrightarrow \frac{a+b}{2} > \frac{c+d}{2}, \tag{6}$$

3. Results and Discussion

Initially the barriers are identified by doing extensive literature survey and taking experts opinion in this regard [16]. The experts are from academia, industry and public-private organizations. This study takes into account all types of barriers to smart cities development in India; which are mentioned in the related literature. The number of sub-factors under each category is same in order to maintain the homogeneity of calculation. Later these are grouped in six categories namely social, political, legal, ethical and technological for ease of carrying out effective analysis. These sub-factors and factors when summarized can be illustrated as follows:

- *Political Factors:* These factors are crucial to be considered is this regard since all policies and financial aid is being issued from government agencies. These sub-factors within this could be lack of trust between governed and the government together with lack of developing a common information system model as given in [33-34].

- *Economic Factors:* These factors are of utmost importance since all companies whether national, international directly get affected by these factors. The sub-factors within this may be the cost of high infrastructure together with training & skill development as mentioned in [35].
- *Social Factors:* The present work deals with the barriers to smart cities development in India. This has direct association with demographic changes which are happening all around the globe [30]. Social factors includes sub-factors such as lack of citizen's participation together with low consciousness of the community.
- *Technological Factors:* It is also an important factor that should be taken into consideration since this factor has direct implication on the quality of services which are required for development of smart cities. The sub factors here are lack of technological knowledge, privacy and security issues as mentioned in [36-37].
- *Environmental Factors:* The sustainability consideration is one of factor that is always taken in mind when such projects are undertaken. The sub-factors under Environmental factors are lacking ecological view in behavior and lack of sustainability considerations [33] [38].
- *Legal & Ethical Factors:* These factors mainly include cultural issues and issues in openness of data [35] [39]. Figure 3 below gives the grouping of sub-factors in six different main factors.

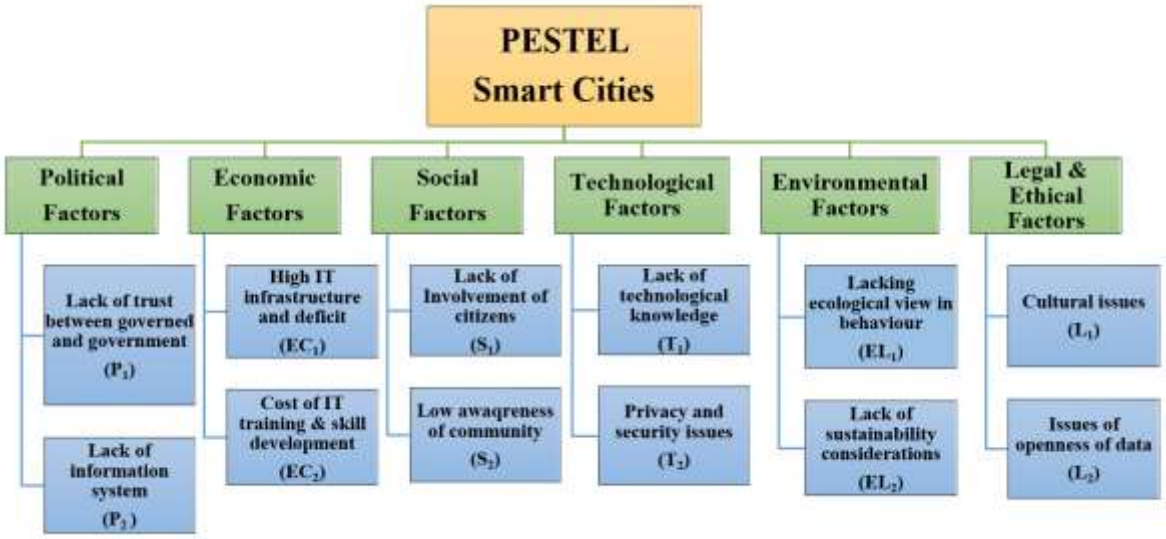

Figure 4 PESTEL hierarchical model for identifying key barriers to smart cities development in India.

Since, all above mentioned factors which are analyzed using PESTEL technique are always linguistic. Therefore in order to analyses them, these factors need to be quantified so to obtain higher interpretability. In order to quantify all the linguistic terms the technique of neutrosophic cognitive maps [31] is used. Now taking in account all the factors which are being considered in this study for analyzing the barriers to smart cities development in India, the NCM is formed. Later this cognitive mapping is used to form the neutrosophic adjacency matrix which forms the basis of all our further calculations. This adjacency matrix is represented in Table 1 below.

Table 1 Neutrosophic Adjacency Matrix

Variables	P1	P2	EC1	EC2	S1	S2	T1	T2	EL1	EL2	L1	L2
P1	0	0	0	-0.37	0	0	0	0	0	0	0	0
P2	0	0	0	0	0	0	0.31	0	0	0	0	0
EC1	0	0	0	0	0	0	0	0	0	0	0	0
EC2	0	0	0	0	0	0	0	0.37	0	0	0	0
S1	0.49	I	0	0	0	0	0.37	0	0	0	0	0
S2	0	0	0	0	I	0	0	0	0	0	0	0

T1	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0.46	0	0	0	0	0	0	0	0
EL1	0	0	0	0	0	0	0	0	0.31	0	0	0
EL2	0	0	0	0	0	0	0	0	0	0	0	0
L1	0	0	0	0	0	0	0	0	0	0.37	0	0
L2	0	0	0	0	0	0	0	0	0	0	0	0.25

Now for static analysis of factors the measures of centrality are calculated. The calculation which is required for calculating the measures of centrality is done using equations 2, 3 and 4. These measures of centrality are based on in-degree and out-degree measures. Table 2 below shows the measures of centrality.

Table 2 Measures of centrality, out-degree, and in-degree

Node	Id	Od	Total degree
P1	0.49	0.37	0.86
P2	I	0.31	I+0.31
EC1	0	0	0
EC2	0.83	0.37	1.20
S1	I	I+0.86	2I+0.86
S2	0	I	I
T1	0.68	0	0.68
T2	0.37	0.46	0.83
EL1	0.31	0.31	0.62
EL2	0.37	0	0.37
L1	0	0.37	0.37
L2	0.25	0.25	0.50

3.1 Results

The results are obtained after the process of de-neutrosophication. This may be referred from Salmeron and Smarandache's work in [25]. *'I'* is replaced by minimum and maximum values in the range *(0, 1)*. The results which are obtained in Table 2 above are being converted to intervals if it contains a value which is indeterminate i.e. *'I'*. Further the de-neutrosiphication function which is represented using symbol ∂ is applied according to equation number 5. The value of ∂ forms the basis for setting up orders of preferences of the barriers which put hindrance to the smart cities development in India. It is represented in Table 3.

Table 3 Total degree, de-neutrosophicated and ordinal number of every variable

Variable	Final Value	∂ (Vi)	Order of Preference
P1	0.86	0.86	3
P2	[0.31, 1.31]	0.81	5
EC1	0	0	10
EC2	1.20	1.20	2
S1	[0.86, 1.86]	1.36	1
S2	[0, 1]	0.50	8
T1	0.68	0.68	6
T2	0.83	0.83	4
EL1	0.62	0.62	7

EL2	0.37	0.37	9
L1	0.37	0.37	9
L2	0.50	0.50	8

According to neutrosophic PESTEL analysis the results obtained are as follows$S1 > EC2 > P1 > T2 > P2 > T1 > EL1 > L2 > L1 > EC1$. The symbol '>' indicates the preference of the factor over the other. This shows the comparison among sub-factors indicating at ground level the importance of each sub-factor. But if comparison is needed taking in consideration all the factors the average of sub-factors corresponding to particular factor is taken. Later this average is converted in percentage and the results are shown using following pie chart in Figure 4.

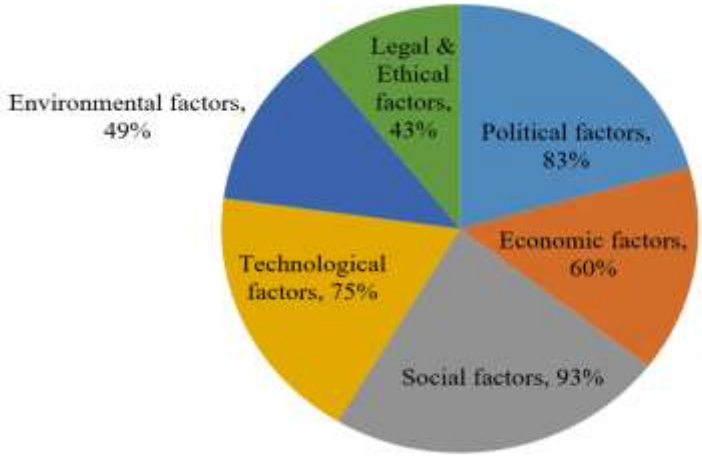

Figure 5 Neutrosophic PESTEL Analysis by Factors

Now overall PESTEL analysis of the factors is done. The results obtained indicate that social factors and political factors are the key barriers to the smart cities development in India contributing for 93% and 83% respectively. Technological and economic factors come at second position contributing 75% and 60% respectively. Environmental and legal factors come at last securing 49% and 43% respectively.

4. Conclusion

The present work seeks to find out the key barriers linked to smart cities development in India using neutrosophic PESTEL technique. The present work contributes to existing research in the related field by providing more realistic modelling of the situation using Neutrosophy which as per our knowledge is not applied in this regard earlier. This work is the need of the hour since there are many projects of the Government, for the development of smart cities, but these are not attaining their expected on-time results due to some uncertain reasons. In the present work, a comprehensive literature review through various literature surveys has disclosed various factors and sub-factors putting hindrance in such projects. Since PESTEL analysis deals with political, economic, social, technological, environmental and legal factors, these sub- factors are grouped in six key barriers. These barriers are modelled using neutrosophic cognitive maps for quantitative analysis and later neutrosophic adjacency matrix is formulated. Further, a comprehensive static analysis is done in order to identify and prioritize the key barriers. The findings of current research are mentioned below:

- The social and political factors contributing 93% and 83% respectively are the key barriers to the development of smart cities in India.

- Technological and economic factors come at second position contributing 75% and 60% respectively as a barrier.
- Environmental and legal factors come at last securing 49% and 43% respectively.

The present works also demonstrate that neutrosophic PESTEL analysis can be applied to more complex problems. Future work in this regard includes implementing and designing machine learning algorithms for carrying out the simulation using neutrosophic theories. Earlier proposed algorithms in machine learning for PESTEL analysis might be combined with neutrosophic approaches so that the output obtained could be validated with more optimized results.

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