

# FuzzyAHP-Based Micro and Small Enterprises' Cluster Identification

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**Abstract:** Micro and Small Enterprises (MSEs) cluster is a group of small firms operating in a defined geographic location, producing similar products or services, cooperating and competing with one another, learning from each other to solve internal problems, setting common strategies to overcome external challenges, and reaching distance markets through developed networks. During recent years, identifying MSEs cluster has become a key strategic decision. However, the nature of these decisions is usually complex and involves conflicting criteria. The aim of this paper is to develop a Fuzzy AHP-based MSEs cluster identification model. As a result, quantitative and qualitative factors including geographical proximity, sectorial concentration, market potential, support services, resource potential and potential entrepreneurs are found to be critical factors in cluster identification. In this paper, linguistic values are used to assess the ratings and weights of the factors. Then, AHP model based on fuzzy-sets theory will be proposed in dealing with the cluster selection problems. Finally, a case study was taken to prove and validate the procedure of the proposed method. A sensitivity analysis is also performed to justify the results.

**Keywords:** Fuzzy-AHP, MSEs cluster, Cluster identification.

## I. Introduction

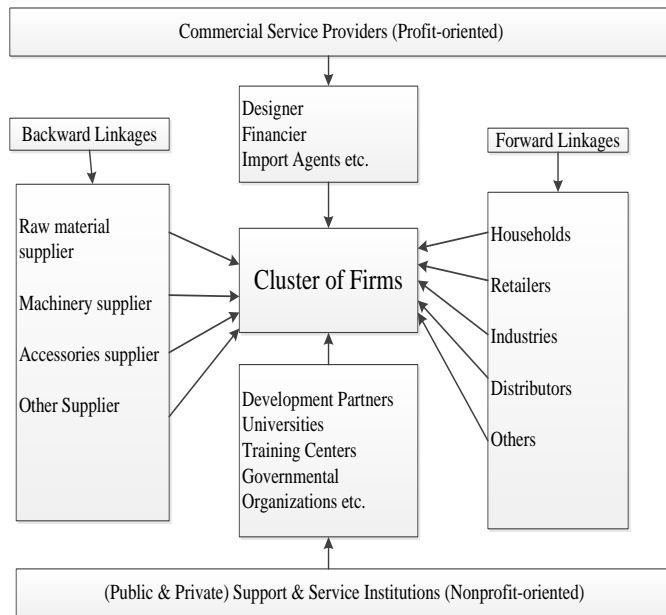
Micro and Small Enterprises (MSEs) are generally recognized as a main contributor to economic growth and equitable development. Their contribution to employment generation and poverty reduction opens a wider opportunity for developing countries. However, the role of MSEs is not often realized because of a set of problems and limitations they encounter towards their path to establishment and growth. Among others, they are facing problems associated with capital, skill, schooling, information, technical knowhow, simplicity and quality of products. MSEs operating

independently would also face difficulty in attracting traders, as trading cost per transaction would be disproportionately high. In the literature, cluster approach is seen to be the viable approach in view of developing small enterprises to overcome the challenging competition for survival [24], [22], [23], [30].

MSEs cluster is a concentration of interconnected, geographically close firms operating together within the same commercial sector and whose activities rely on certain local specificities such as availability of natural resources, centres for technological development (through universities, research centres, technology parks, or a technology-based industry), and a consolidated productive structure for all tiers of the productive chain of a region [20]. As shown in figure 1, a cluster is an agglomeration of firms, suppliers, service providers, and associated institutions in a particular field. Often, financial providers, educational institutions, and various levels of government are included. These entities are linked by externalities and complementarities of different types and are usually located near each other. Geographic proximity helps cluster constituents to enjoy the economic benefits of several location-specific externalities and synergies [24]. Concept of cluster suggests connection and association of firms that are linked vertically and horizontally through their commonalities and complementarities in products, services, inputs, technologies, transportations, warehouse and communication [22]. Research has extended Porter's theory to different types of industries where clusters are viewed as a way to maintain global competitiveness.

In this globalized world, economic success will only come by integrating the societies and economies. Ability of a nation or a region to succeed in today's global economy depends directly on its ability to create an economic relevance at the national as well as at the global level. According to Sonobe and Otsuka, a cluster approach is the most feasible approach

for developing small enterprises [30].



**Figure 1.** Typical cluster map

There are different arguments regarding the methods and techniques used for identifying clusters [1]. Generally, the choice of method for cluster mapping depends on the kind of clusters wanted to be identified. As summarized by Yoo, (2003) and Andersen and his colleagues, (2006), there are five widely used cluster identifying methods. These are: Expert Opinion, Location Quotients (LQ), Input-Output Analysis, Network Analysis/Graph Analysis and Surveys.

Expert opinion gathers information by interview, focused group discussion, Delphi method and other means of gathering key informant's information [33]. The methodology of asking experts, however, has some limitations, such as: there is a risk of getting a subjective opinion about the clusters area in question. This form of identification is also difficult to standardize and compare across regions and national borders which is an impediment to benchmarking. Nonetheless, the approach is a good supplement to other identification methods.

Location Quotient (LQ) measures the extent to which a region is more specialized in an industry compared to the geographic area in question [1]. This methodology is very simple and easy to use [28]. However, it says absolutely nothing about regional MSEs clusters and offers no insight into interdependences between sectors [3]. Another limitation of the LQ technique is that it can be used in only bottom-up analyses as one of several measures of sector performance. The choice of regions must be made before the clusters can be identified. Although the sizes of the regions can be altered in order to find a best fit, only one choice of regional aggregation can be made before the actual mapping [1]. Therefore, the result of this method is not fully relevant for cluster formation decision [28].

Input-output Analysis seems to be used most widely and frequently [9]. Although, this analysis can overcome the limitation of the LQ technique, it lacks of concern for interdependence between sectors. Therefore, input-output analysis is especially useful in an analysis of a

vertically-integrated cluster, in which the buyer-seller linkages are more obvious [1]. There are two type of input-output cluster identification techniques : (1) Input-output analysis of business relationships (IOA) and (2) Input-output analysis of innovations. The first method can identify the relationships among firms which are necessary for cluster initiatives. The drawbacks of this method are quick obsolescence, low accuracy and the inability of its application in small regions [28]. The limitation of the second method is that, it does not actually focus on the clusters [28].

Network Analysis/Graph Analysis is a very good method of finding networks and social capital that can refer to individual connections compared to a general term of networks [33]. This method is mostly applied as a visualization tool [28].

Survey is one of the methods frequently-used to identify industry clusters. However, it seems that the cases using only surveys are rare and very expensive. Thus, many empirical reports seem to use surveys in conjunction with other quantitative methods.

Finally, AHP is the best method for cluster identification. Because it can handle both qualitative and quantitative, often conflicting criteria at the same time [17]. But it has limitation during the presences of uncertainty and ambiguity in deciding the priorities of different alternatives. Table 1 shows the advantages and pitfalls of each method.

From the above methods it has been clearly seen that cluster identification process is a complex process that involves both qualitative and quantitative, often conflicting criteria. There is no single method which incorporates the two criteria together. To solve this limitation this paper introduces multi-criteria decision-making (MCDM) technique. The most important advantage of MCDM techniques is that it can include both qualitative and quantitative data [10]. The aim of this paper is to contribute a tested model for Micro and Small Enterprises cluster identification. Basically, the new model will solve the pitfalls with the cluster identification methods and approaches.

Multi-Criteria Decision-Making (MCDM) is a powerful tool used widely for solving problems with multiple, and usually conflicting, criteria [21]. The most important advantage of MCDM techniques is to analyze and synthesize both qualitative and quantitative data [10]. With this characteristic, decision-makers have the possibility to easily examine and scale the problem in accordance with their requirements. Some of the commonly used MCDM techniques are AHP, Fuzzy-AHP, Analytic Network Process (ANP) and Technique for the Order of Prioritization by Similarity to Ideal Solution (TOPSIS). In this paper Fuzzy-AHP is used to develop MSEs cluster identification model.

The rest of the paper is organized as follows: Section II explores the literature review; Section III presents research methodology. Section IV presents results and discussions. Finally, Section V presents the conclusions.

**Table 1.** Methods of identifying cluster [33]

Method	Advantage	Pitfalls
Expert opinion	Very easy, low cost, detailed contextual information	It's just opinion, not axiom
Location Quotients (LQs)	Very easy, inexpensive, can supplement other methods	Focuses on sectors, not clusters
Input-output analysis	Comprehensive and detailed, key measure of interdependence	May be dated, industry definitions imperfect; neglect supporting institutions
Network analysis	Visualization aids interpretation and analysis	Software still limited
Surveys	Flexibility with collecting ideal data, up-to-date	Costly, difficult to implement properly
AHP	Simple structure and design, which represent human mind and nature	Cannot handle the uncertainty

## II. Literature Review

### A. AHP and Fuzzy-AHP

The Analytic Hierarchy Process (AHP), introduced by Saaty, is a useful and practical tool that provides the ability to incorporate both qualitative and quantitative factors in the decision-making process [7]. AHP is a powerful method to solve complex decision problems. Any complex problem can be decomposed into several sub-problems using AHP in terms of hierarchical levels, where each level represents a set of criteria or attributes relative to each sub-problem [6]. One of the main advantages of the AHP method is the simple structure and design which represent human mind and nature [34]. But, it is generally criticized by the use of a discrete scale of 1-9 which cannot handle the uncertainty and ambiguity present in deciding the priorities of different attributes [7]. To overcome these problems, several researchers integrate fuzzy theory with AHP to improve the uncertainty. The use of Fuzzy-AHP for multiple criteria decision-making requires scientific approaches for deriving the weights from fuzzy pair-wise comparison matrices [32]. Recently, Fuzzy-AHP has been widely used to solve multi-criteria decision problems; so far, Washing machine company supplier selection by Kilincci and Onal [13], Computer-aided maintenance management systems by Durán [8], Intelligent timetable evaluation by Isaai and his colleagues [10], Flexible manufacturing system (FMS) by Shamsuzzaman and his colleagues [25], To prioritize enabling factors for strategic management of university business incubators by Somsuk and Laosirihongthong [27], To manage intellectual capital assets by Calabrese and his colleagues [4], To embed relevant data on communicating material by Kubler and his colleagues [14] and To identify industrial cluster by Netsanet and her colleagues [18] are some of the published works.

However, up to now, no research has been conducted on Fuzzy-AHP for identification of industrial clusters, particularly for MSEs which have critical contribution to the developing and developed countries.

### B. Fuzzy Sets and Numbers

Decision-making is very difficult for unclear and uncertain environment. This vagueness and uncertainty can be handled

by using fuzzy set theory, which was proposed by Zadeh (1965) [26]. Fuzziness and vagueness are normal characteristics of a decision-making problem [11]. A major contribution of fuzzy set theory is its capability of representing vague or uncertain data in a natural form.

Fuzzy theory is composed of three key factors: fuzzy set, membership function, and fuzzy number to change vague data into useful data efficiently [16]. The merit and strength of using fuzzy approach is to express the relative importance of the alternatives and the criteria with fuzzy numbers instead of using simple crisp numbers as most of the decision-making problems in the real world takes place in a situation where the pertinent data and the sequences of possible actions are not precisely known [16].

Triangular and trapezoidal fuzzy numbers are usually used to capture the vagueness of the parameters which are related to select the alternatives [16]. Triangular Fuzzy Numbers (TFN) are expressed with boundaries instead of crisp numbers for reflecting the fuzziness as decision-makers select the alternatives or pair-wise comparisons matrix. This paper used TFN to prioritize MSEs cluster areas with fuzziness.

To explain this information in mathematics, a fuzzy set which is a class of objectives with continuum grades of membership was developed. A membership function in fuzzy sets assigns to each object, a grade of membership in [0, 1] [13]. A triangular fuzzy number (TFN),  $\mu_M(x)$  is shown in figure 2. Each membership function is defined by three parameters of the symmetric triangular fuzzy number,  $(l, m, u)$ . The parameters  $l, m,$  and  $u$  denote the smallest possible value, the most promising value and the largest possible value that describe a fuzzy event respectively [12].

Some basic definitions of the fuzzy sets and fuzzy numbers are discussed below [7], [13].

**Definition 1.** Let  $X$  be a space of points, with an element of  $X$  denoted by  $x$ . A fuzzy set  $M$  in  $X$  is characterized by membership function  $\mu_M, [0, 1]$  which is assigned to represent the grade of membership of  $x$  to  $M$ . Thus, the nearer is the value of  $\mu_M$  to unity, the higher is the grade of membership of  $x$  to  $M$ .

**Definition 2.** The membership function of a triangular fuzzy number  $M$ , denoted by triplet  $(l, m, n)$ , is defined as

$$\mu_M(x) = \begin{cases} 0, & x < l \\ \frac{x-l}{m-l}, & l \leq x \leq m \\ \frac{u-x}{u-m}, & m \leq x \leq u \\ 0, & x > u \end{cases} \quad (1)$$

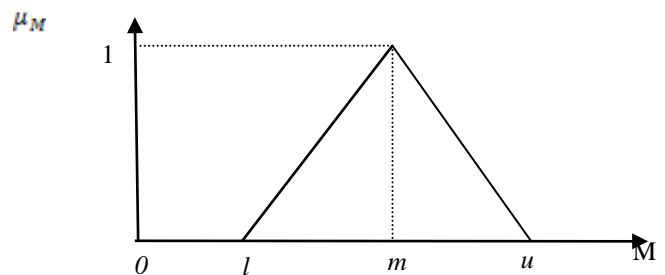


Fig. 2. Membership function of a triangular number.

**Definition 3.** Consider two triangular fuzzy numbers and  $M_1$  and  $M_2$ ,  $M_1=(l_1, m_1, u_1)$  and  $M_2=(l_2, m_2, u_2)$ . Their operational laws are as follows [7, 15]:

$$(l_1, m_1, u_1) + (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (2)$$

$$(l_1, m_1, u_1) * (l_2, m_2, u_2) = (l_1 l_2, m_1 m_2, u_1 u_2) \quad (3)$$

$$(l_1, m_1, u_1)^{-1} = (1/u_2, 1/m_2, 1/l_2) \quad (4)$$

*Extent Analysis Method on Fuzzy-AHP*

The surveyed literatures show that the vast majority of the Fuzzy-AHP applications use a simple extent analysis method proposed by Chang,(1996) [5]. The extent analysis method is used to consider the extent of an object to be satisfied for the goal, that is, satisfied extent [13]. In the method, the ‘‘extent’’ is quantified by using a fuzzy number. The basics of the extent analysis method on Fuzzy-AHP are introduced as applied for a washing machine company supplier selection by Kilincci and Onal [13] and applied for Intelligent timetable evaluation by Isaai and his colleagues [10].

Let  $X=\{x_1, x_2, \dots, x_n\}$  be an object set, and  $U=\{u_1, u_2, \dots, u_m\}$  be a goal set. According to Chang’s extent analysis, each object is taken, and extent analysis for each goal,  $g_i$ , is performed, respectively [5]. Therefore,  $m$  extent analysis values for each object can be obtained, with the following signs:

$$M_{g_i}^1, M_{g_i}^2, \dots, M_{g_i}^m, \text{ Where } i = 1, 2, \dots, n \quad (5)$$

Where all the  $M_{g_i}^j (j = 1, 2, \dots, m)$  are TFNs.

The steps of Chang’s extent analysis can be given as in the following steps:

1. The value of fuzzy synthetic extent with respect to the  $i^{th}$  object is defined as:

$$S_i = \sum_{j=1}^m M_{g_i}^j * [\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j]^{-1} \quad (6)$$

To obtain  $\sum_{j=1}^m M_{g_i}^j$ , perform the fuzzy addition operation of  $m$  extentalanalysis values for a particular matrix such that:

$$\sum_{j=1}^m M_{g_i}^j = \left[ \sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j \right] \quad (7)$$

and to obtain  $[\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j]^{-1}$  perform the fuzzy addition operation  $M_{g_i}^j (j = 1, 2, \dots, m)$  values such that:

$$\left[ \sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j \right]^{-1} = \left( \frac{1}{\sum_{i=1}^n u_i}, \frac{1}{\sum_{i=1}^n m_i}, \frac{1}{\sum_{i=1}^n l_i} \right) \quad (8)$$

2. The degree of possibility of  $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$  is defined as follows:

$$V(M_2 \geq M_1) = \sup_{y \geq x} [\min(\mu_{M_1}(x), \mu_{M_2}(y))] \quad (9)$$

and can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) \quad (10)$$

$$= \begin{cases} 1, & \text{if } m_2 \geq m_1, \\ 0, & \text{if } l_1 \geq u_2, \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{otherwise,} \end{cases} \quad (11)$$

Where  $d$  is the ordinate of the highest intersection point  $D$  between  $\mu_{M_1}$  and  $\mu_{M_2}$ . In Fig. 3, the intersection between  $M_1$  and  $M_2$  can be seen. To compare  $M_1$  and  $M_2$ , both the values of  $V(M_1 \geq M_2)$  and  $V(M_2 \geq M_1)$  are needed.

3. The degree of possibility for a convex fuzzy number to be greater than  $k$  convex fuzzy numbers  $M_i (i = 1, 2, \dots, k)$  can be defined by:

$$V(M \geq M_1, M_2, \dots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \dots \text{ and } (M \geq M_k)] = \min V(M \geq M_i), i = 1, 2, 3, \dots, k \quad (12)$$

Assume that

$$d(A_i) = \min V(S_i \geq S_k) \quad (13)$$

For  $k = 1, 2, \dots, n; k \neq i$ , then the weight vector is given by:

$$W' = ((d'(A_1), d'(A_2), \dots, d'(A_n))^T \quad (14)$$

Where  $A_i (i = 1, 2, \dots, n)$  are  $n$  elements.

4. Via normalization, the normalized weight vectors are:

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T \quad (15)$$

Where  $W$  is a nonfuzzy number. This gives the priority weights of one alternative over another.

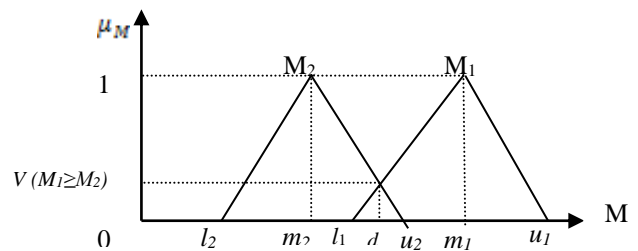


Fig. 3. The comparison of two fuzzy number

As illustrated above, extent analysis method on Fuzzy-AHP is used to solve multi-criteria decision problems. The paper used this approach to identify MSEs cluster.

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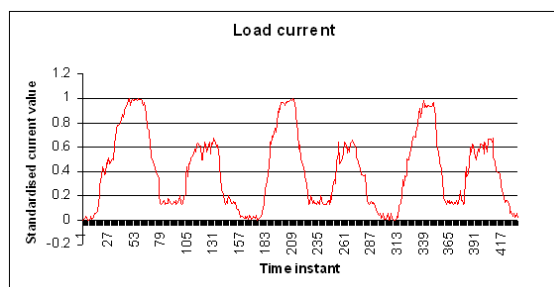


Figure 1. Testing data- load current (amperes)

##### 2) Tables

Place table titles above the tables.

Method	Best result	Average result
Fuzzy systems	0.24	0.30
Genetic algorithms	0.17	0.28
Neural Networks	0.20	0.27

Table 1. Comparison of results.

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$$E = \sum_{p=1}^P \sum_{k=1}^K (\delta_{pk}^o)^2 \quad (1)$$

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#### Acknowledgment


Please provide acknowledgement only after the conclusion section.

#### References


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200001, Indian Institute of Technology, Kanpur, India, 2000. (technical report style)


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