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# The evaluation of cluster policy by fuzzy MCDM: Empirical evidence from HsinChu Science Park

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ABSTRACT

In the recent years, industrial clusters have received considerable attention from economists and industrial analysts, because they are seen as the main reason for economic growth and success of certain economic region. This study systematically reviews past researches of industrial cluster. The purpose of this paper is to contribute to the understanding of this issue regarding the driving forces for the growth of industrial cluster and find out the priority among these cluster policies. Taiwan HsinChu Science Park is a prime example for this paper, and its connection with the innovative participators. We begin with an examination of the literature on cluster about its driving forces and policies upon which we propose a conceptual framework. In doing so, we explore the cluster-based industrial system. Then this research adopts the Fuzzy Analytic Hierarchy Process as the analytical tool. The Fuzzy Analytic Hierarchy Process method is used to determine the weightings for evaluation dimension among decision makers. From our research results, the Factor Conditions is the most important driving force for advancing the industrial cluster performance. Moreover, the promotion of international linkages policy and broader framework policies rank the first two priorities for cluster policy. Overall, this paper concludes with some simulations of cluster policy alternatives confronting the industry and the Taiwanese government.


## 1. Introduction

The increasing competition and globalization of industries, markets, and technologies have raised the demand for outside-in innovation and acquisition of technology through integrated innovation cluster (Becker & Gassmann, 2006). Companies need to develop cluster competence in order to link their organization to other players in the market to allow interactions beyond organizational boundaries (Ritter & Gemunden, 2004). The formation of clusters of innovation is a useful concept to transform both tangible and intangible knowledge into embodied and disembodied technical change (Liyanage, 1995).

Clusters are defined as selected sets of multiple autonomous organizations, which interact directly or indirectly, based on one or more alliance agreements between them. The aim of clusters is to gain a competitive advantage for the individual organizations involved and occasionally for the cluster as a whole as well. Cluster competence enables a company to establish and use relationships with other organization (Ritter & Gemunden, 2004).

On the other hand, the traditional industrial system has often focused on promoting science and technological policies. These system models have typically believed in the science push effect in radical industrial process. Compared with traditional hierarchical systems, the cluster between industries and other research institutions can reduce innovation costs (Clark & Guy, 1998; Gemunden, Ritter, & Heydebreck, 1996), gain complementary resources or knowledge (Ritter & Gemunden, 2004; Teng, Tseng, & Chiang, 2006; Williams, 2005), receive financial funds (Colombo & Delmastro, 2002; Rothschild & Darr, 2005), and advance competitive positions (Ritter & Gemunden, 2004).

Previous studies also have examined the cluster structure (Clark & Guy, 1998; Gemunden et al., 1996; Ritter & Gemunden, 2004), and some studies addressed the cluster effect (Teng et al., 2006). A number of empirical studies also provide evidences that clusters affect the innovation performance (Colombo & Delmastro, 2002). Particularly, over the past researches, scholars in the field of innovation system have found it most useful to compare the innovation system between different industries or countries (Chang & Shih, 2005).

Some scholars have draw attention to Taiwan innovation system (Hu, Lin, & Chang, 2005; Lai & Shyu, 2005; Lee & Tunzelmann, 2005; Tasi & Wang, 2005; Yang, Chia-Han, Cheng, & Shyu, 2006). Taiwan is one of the world's largest manufacturers of high-technology components and products. Taiwan maintains its current competitive position through investment in research and development (Lai & Shyu, 2005; Tasi & Wang, 2005). To this end, the

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establishment of a business friendly environment and local innovation cluster, and the creation of an environment to enhance innovation capabilities, is a pressing task (Hu et al., 2005). The development of high-tech industry has obviously reached maturity in Taiwan. According to the World Economic Forum's "2007–2008 Global Competitiveness Report", Taiwan has again taken first place in the world in the "State of Cluster Development" index (see Appendix A) (Chen, 2007).

The HsinChu Science Park (HSP) of Taiwan is now one of the world's most significant areas for semiconductor manufacturing.It is home to the world's top two semiconductor foundries, Taiwan Semiconductor Manufacturing Company (TSMC) and United Microelectronics Corporation (UMC) (Chen, 2007; Lai & Shyu, 2005; Tasi & Wang, 2005). The HSP was established by the government of Taiwan in 1980. It straddles HsinChu City and HsinChu County on the island of Taiwan. Industries in the HSP cover primarily six spheres – semiconductor, computer peripherals, communications, opto-electronics, biotechnology, and precision machinery. Firms in the science parks bring in high-tech industries, and in addition, help transform Taiwan's labor-intensive industries into technology-intensive industries.

In the literature, there is no fuzzy logic method aimed at prioritizing the cluster policies. The main purpose of this paper is to provide practitioners with a fuzzy point of view to traditional policy research for dealing with imprecision and at obtaining the prioritization of driving forces measurement dimensions. Moreover, we attempt to assist government representatives or industrial analyst in accessing cluster policy. We take the HSP of Taiwan for pursuing our case purposes. This research invites ten experts that evaluate different cluster policy via the proposed fuzzy AHP method. This research looks forward to provide Taiwan industries and government with some strategic recommendations.

The reminder of this paper is as follows: Section 2 briefs the factors drive the growth of industry clusters rooted in important prior researches. Section 3 introduces the cluster policies. Section 4 presents how we adopt the methodology, Fuzzy AHP. Section 5 displays our empirical results along with some discussions relating to managerial implications. Concluding remarks are then given in Section 6.

## 2. What factors drive industrial cluster as national competitiveness?

A major breakthrough for the cluster concept was Porter's Competitive Advantage of Nations (1998) which advocated specialization according to historical strength by emphasizing the power of industrial clusters. Porter highlighted that multiple factors beyond the ones internal to the firm may improve its performance. In his "diamond model", four sets of interrelated forces are brought forward to explain industrial cluster. These are associated with factor input conditions; local demand conditions; related and supported industries; and firm structure, strategy and rivalry.

National competitive advantages achieved by industrial cluster (Cooke, 2001; Enright, 1992, 1993; Porter, 1998). In high competitive and global environment, regional industrial cluster provide a valuable mechanism for boosting national competitiveness. Clusters are the key organizational unit for understanding and improving the performance of national economies and competitiveness. An industrial cluster is a geographic concentration of interconnected businesses, suppliers, service providers, and associated institutions (Mills, Reynolds, Reamer, & Andrew, 2008). That is, the industrial clusters stimulate innovation and improve productivity; they are a critical element of national competitiveness. They also provide a unique environment for accelerating technological innovation, nurturing new start-up firms, attracting investment and generating the economic growth. In summary, industrial clusters improve national competitiveness by increasing in both inter-organization and industrial productivity, advancing innovation capability and urging new enterprise formation (Lin, Tung, & Huang, 2006).

In addition, national cultures and cultural differences can be used as a source of competitive advantage. It is therefore important to recognize cluster's own cultural benefits and deficits. Where deficits are identified, benchmarking those cultures which offer cultural solutions to those deficits can be undertaken. Our research therefore also attempts to provoke discussion on the value of looking at the growth of cluster in the light of cultural influences. This could be used to help determine the catalytic role that such development organizations should be playing by emphasizing the need to base decision making on cultural as well as economic factors in order to stimulate cluster formation and enable innovation by optimizing cultural interchange. The culture of the cluster influences the culture of the workforce and the culture of business. A cultural understanding of operations excellence is critical to success. Suppliers can learn from performance evaluation about the need to improve supervision, precision, cycle time and skills, and to participate in improvement projects.

In the high competitive industry environment, industries need to establish a cluster that share information and resources to attain the synergy-effect among the firms and finally to increase its national competitive advantages. Therefore, we should find out what the driving forces for those industrial clusters are. We chiefly adopt the concepts of Diamond Model (Porter, 1998) adding in the factor of culture for deducing which most important cluster driving forces are and as a base analyzing the relationship and impacts among those forces, in the notion of industrial clustering toward national competitiveness.

### 2.1. Factor conditions

Porter agreed that a state's or nation's endowment of factors of production has a role in determining competitive advantage. However Porter broadened the definition of factors of production into five major categories: human resources; physical resources; knowledge resources; capital resources; and infrastructure (Rojas, 2007).

Abundant natural resources, which are factors of production, could provide the original momentum for establishing an industry. Their presence might also have enticed a predecessor industry to the location, thereby creating the initial framework for a subsequent industry (Porter, 1998).

Competitive pressure compelling firms to innovate in order to overcome their microeconomic environment's disadvantages represents a major theme in Porter's work. The remaining fundamental determinants in the model play an important and powerful role in inciting firms to innovate so as to remain competitive players in their industries. Specialized factors of production are skilled labor, capital and information infrastructure. Specialized factors involve heavy, sustained investment. They are more difficult to duplicate. The factors include entrepreneurship, venture capital and so on.

Entrepreneurship is the engines of cluster development growth. Entrepreneurs play an important role in selecting and applying new ideas. The venture capital investment plays a vital role in creating phenomenal economic growth (Wonglimpiyarat, 2008). Finally, the science and information infrastructure mean that a country or region establish a science and technology platform for improving or upgrading science linkage between players, such as science park or information center. The science park concept was originated in the late 1950s. The idea was, and still is, to provide a technical, logistical, administrative, and financial infrastructure to help young enterprises gain a toehold for their products in an increasingly competitive market.

### 2.2. Local demand conditions

Consumer demand dominates an important role in forming and building up an industrial cluster. A large number of industrial customers in the nearby area created sufficient demand to enable suppliers to acquire and operate expensive specialized machinery.

Porter (1998) argues that a sophisticated domestic market is an important element to producing competitiveness. Firms that face a sophisticated domestic market are likely to sell superior products because the market demands high quality and a close proximity to such consumers enables the firm to better understand the needs and desires of the customers (Lai & Shyu, 2005). As a result, demand conditions can stimulate an industry through local demand for a product that proves viable in regional, national, and international markets (Woodward, 2004).

### 2.3. Related and supporting industries

Spatial proximity of upstream or downstream industries facilitates the exchange of information and promotes a continuous exchange of ideas and innovations. The availability, density, and interconnectedness of vertically and horizontally related industries are an important driver for industrial cluster (Lai & Shyu, 2005). This includes suppliers and related industries.

Related industries refer to firms that provide complementary products or services to one another. While competing on the basis of their value chain management within their product- or service-specific industry, they might share or coordinate certain activities such as distribution, technology development, manufacturing, or marketing (Porter, 1998). Competitive related industries can provide opportunities for technological exchanges and, possibly, accelerate the development of competitive local supplier industries serving both. However, close working relationships among related industries do not happen automatically. Related industries must explicitly seek to forge alliances that will add to their competitive advantage (Rojas, 2007).

Close working relationships between downstream firms and local input suppliers can facilitate the process of innovation and upgrading (Porter, 1998). Related and supporting industries could drive the creation of an industry through spin-offs, serving a particular market that is outside the realm of another local industry (Rojas, 2007).

### 2.4. Firm structure, strategy and rivalry

Porter (1998) argues that intense competition spurs innovation. The world is dominated by dynamic conditions. Direct competition impels firms to work for increases in productivity and innovation. Firm strategy, structure, and rivalry refer to the various approaches to a firm's inception, organization, and management that establish the context for local rivalry and competitive advantage. Differences in management systems and organizational structure offer opportunities for establishing competitive advantage. Relationships between labor and management represent a particularly important element for the firm given their powerful impact on the process of innovation and improvements (Porter, 1998). Porter established that rivalry with domestic firms proved more beneficial in terms of innovation and improvements. Local rivals compelled one another to seek effective cost-cutting measures, product/service innovations, and organizational improvements. Local competitive pressure led to commercially successful firms, which in turn, lured new firms to the industry.

Rivalry is the key element to compel the initial industry to become a competitive one through upgrading and innovation. A cluster of domestic rivals encourages the formation of more specialized suppliers and related industries. The geographic proximity in the cluster between rival firms and their suppliers or related industries facilitates research exchanges and collaboration. This broadens the depth, breadth, and specialization of the cluster, thereby inducing further investment in advanced infrastructure and factor creation (Rojas, 2007).

### 2.5. Government support

The role of government in the Diamond Model of Porter is to act as a catalyst and challenger; it is to encourage – or even push – companies to raise their aspirations and move to higher levels of competitive performance. Government must encourage companies to raise their performance, to stimulate early demand for advanced products, to focus on specialized factor creation and to stimulate local rivalry by limiting direct cooperation and enforcing anti-trust regulations.

Besides, government must provide the required infrastructural needs of the developing industrial cluster. The role of the government in a regional economy is necessarily variable over the life cycle of the industry cluster, and as a result it needs to have the capability to identify and monitor the set of natural industries that exist within the region, and their stage of development (Porter, 1998). However, government's role requires a paradigm shift, both in 'mind set' and in programs and services (Porter, 1998). In the new paradigm government acts as facilitator, promoting partnerships and alliances, focusing on investments in skills development, infrastructure and new technologies. The government has taken a much more commanding role, encouraging the creation of clusters by offering inducements to companies to relocate there.

### 2.6. Culture

Innovation is an outcome of an innovative culture. Clusters with an innovative culture will increase the life-expectancy and productivity of the infrastructure and business capital which they host and the productivity and prosperity of their community (Porter, 1998). Hall (1976) argued that cultures vary greatly in the processing of information and patterns of communication. Cultural differences were found to predict stress, negative attitudes toward merger, and the lack of cooperation between firms subsequent to merger (Weber, Shenkar, & Raveh, 1996). More relevant to our study, Olie (1994) argued that the blending of diverse cultures tends to be a challenging obstacle to successful collaboration.

## 3. What are industrial cluster policies?

Cluster policy entails a shift of focus from individual firms to local/regional systems of firms and firms' value adding environment. Cluster policy also means less reliance on large firms and more interest in local agglomerations of SMEs. The notion of clusters also leads to stimulating social processes, e.g. encouraging trust-based interaction to increase the flow of knowledge between local players, rather than intervening, for instance, through financial incentives. Cluster policy should organize service delivery. Governments offer training, education, financing, technical assistance, research, and marketing support through different agencies. Organizing the data by cluster and coordinating the collection of survey data through cluster organizations would provide useful information to local development agencies, cluster organizations, and service providers and minimize paperwork demand on companies. In addition, Government can target investment, such as invest in cluster R&D and innovation, establish cluster-specific technology centers or parks, and support cluster-based entrepreneurial activity.

Many governments have policies to encourage applied research and development and to cost-share other resources, including tax credits and matching grant programs. Investments in cluster-based R&D in the short term can help attract new specialized talent and firms to a cluster. In the much long term, such investments many produce new commercial products and generate new companies.

The cluster policy includes five types, such as broker policy, demand side policy, training policy, promotion of international linkages policy, broader framework policies (Andersson et al., 2004).

Broker policies mean that public authorities can support the establishment of linkages between firms through the creation of platforms for dialogue. The platform also provides supports of knowledge-enhancing organization linkages through public–private partnership. The broker policies are the key to the programme, serving as external facilitator, or systems integrator for network functions. In some instances, the brokers are consultants but in most cases brokers worked for agencies already serving SMEs (Andersson et al., 2004). The aim of broker policies is to enable value-enhancing dialogue and collaboration beyond what would be achieved n the absence of initiatives. The broker policies include the creation of platform, protection of intellectual property and support of knowledge-enhancing organizational linkage. The platform can foster cluster development. It not only encourages and facilitates growth of industrial network but also supports to the external connections. In addition, Intellectual property reforms may be reformed so as to provide both the institutions and the individual researchers with an incentive to collaborate industry. Furthermore, the linkages of knowledge-enhancing organization through public–private partnership provide release time, and also create potential learning and benchmarking opportunities in the cluster (Andersson et al., 2004).

Demand side policy aim at increasing openness to new ideas and innovative solutions. One instrument for demand side policy is public procurement. Public Procurement has a strong potential for developing and strengthening clusters. Public procurement will play a role in the development of the construction cluster. Public procurement, which occurs when a public agency acts to purchase, or place an order for, a product – service, good, or system – that does not yet exist, but which could probably be developed within a reasonable period of time, based on additional or new innovative work by the organization(s) undertaking to produce, supply, and sell the product being purchased (Edquist, Hommen, & Tsipouri, 2000). In more concrete terms, there are several ways how public agencies can support innovations, namely via the creation of new markets for products and systems that go behind the state of-the-art; the creation of demand "pull" by expressing its needs to the industry in functional or performance terms; providing a testing ground for innovative products. In order to effectively use the public resources for innovation, public procurement should be concentrated on s clusters relevant to the region or the country. Cabral, Cozzi, Denicoló, Spagnolo, and Zanza (2006) list some aspects that should be taken into account when establishing a policy for procurement for cluster's growth. To stimulate R&D and innovation in financially constrained sectors, the government should increase the current cash flows of innovative firms by buying more at higher prices (Andersson et al., 2004). To stimulate R&D and innovation in sectors that easily raise external capital, the government should commit to a policy that increases innovative firms' future expected profits, for example by promising to buy future innovative goods more and at higher prices. Government expenditure should increase expected profits in sectors in which the supply of the R&D inputs is more elastic and reduce them where they are less elastic. Public procurement should increase expected profits in innovative sectors during recessions or, more generally, when there is excess capacity of R&D inputs (e.g. human capital). Government procurement should make prices and quantities demanded responsive to quality ranking modifications: top quality products should be guaranteed immediate profits whereas for obsolete goods, the public buyer should bargain for very competitive prices. Government expenditure should reduce expected profits in sectors in which the future innovative prospects are low and re-direct R&D towards the more technologically underexploited sectors.

Training policy focuses on upgrading skills and competencies which are essential for effective cluster of SMEs. Apart from catalyzing inter-firm networks and university–industry linkages, cluster processes may strengthen the incentives for SMEs to upgrade their internal competencies. Special programs may be needed to realize and sharpening such effort. Finally, Government agencies should develop human resources (Andersson et al., 2004). They try to develop a more skilled and specialized labor force and establish cluster skills centers. Educators classify their programs by occupation, but the skills used in the workplace are defined by the context in which they are applied. The context varies from industry to industry, from small firms to large firms. Cluster skills centers could become the lead entities for surveying industry needs, developing new curricula, saying in touch with cluster councils, updating skills standards, benchmarking practices in other places, and collecting information about cluster occupations and programs. Skills centers can serve as gateways to help firms bombarded with more information than they can handle determine which training programs are the most familiar with the industry and have the most relevant staff experience, latest technologies, and best track record.

Promotion of international linkages policy means that the elimination of trade barriers and strengthening of transport and communication systems, along with the harmonization of market regulations have greatly improved conditions of resource flows and enhanced specialization of value chain across national borders. Eliminating obstacles to international trade in customs or at border crossings through harmonization, elimination, and/or simplification of customs procedures and duties, the coordination of procedure among customs, health and sanitary authorities, and other entities that affect flows of trade, continuing the line of work started with the regional operation for customs measures to facilitate international business (Andersson et al., 2004). Harmonizing technical trade standards have become a significant barrier facing many exporters in international markets. The objective will be harmonization, elimination, and/or simplification of technical standards and requirements, and mutual recognition of inspection conducted in the country of origin. In addition, government can provide support for the public sector to harmonize, simplify, or eliminate obstacles to international trade. It can also provide information, technical assistance, and training to the private sector, especially small enterprises, to help them meet the technical standards required for international business. Moreover, the government should provide training for exporters in complying with technical standards for access to international markets. The objective here is to provide information to exporters on the range of technical standards and requirements that they must meet to gain access to international markets, and consulting and training services to help them meet those standards.

Broader framework policies focus on an over-riding playing field marked by effective and consistent rules for inter-actor transactions. Relevant framework conditions include macroeconomic stability, well-functioning product market, factor market (labor and financial markets), education systems, and physical, institutional and judicial infrastructure, including a governance system that is able to sustain effective and consistent playing rules for innovation, the existence of an appropriate communications and transport infrastructure (Andersson et al., 2004).

## 4. Fuzzy Analytic Hierarchy Process

Analytic Hierarchy Process (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. The AHP method is a multi-criteria method of analysis based on an additive weighting process, in which several relevant attributes are represented through their relative importance. AHP has been extensively applied by academics and professionals, mainly in engineering applications involving financial decisions associated to non-financial attributes (Saaty, 1996). Through AHP, the importance of several attributes is obtained from a process of paired comparison, in which the relevance of the attributes or categories of drivers of intangible assets are matched two-on-two in a hierarchic structure.

However, the pure AHP model has some shortcomings (Yang & Chen, 2004). They pointed out that the AHP method is mainly used in nearly crisp decision applications; the AHP method creates and deals with a very unbalanced scale of judgment; the AHP method does not take into account the uncertainty associated with the mapping of human judgment to a number; the ranking of the AHP method is rather imprecise; and the subjective judgment, selection and preference of decision-makers have great influence on the AHP results. To overcome these problems, several researchers integrate fuzzy theory with AHP to improve the uncertainty. Hence, Buckley (1985) used the evolutionary algorithm to calculate the weights with the trapezoidal fuzzy numbers. The fuzzy AHP based on the fuzzy interval arithmetic with triangular fuzzy numbers and confidence index $\alpha$ with interval mean approach to determine the weights for evaluative elements.

### *4.1. Determining the evaluation dimensions weights*

This research employs Fuzzy AHP to fuzzify hierarchical analysis by allowing fuzzy numbers for the pair-wise comparisons and find the fuzzy weights. In this section, we briefly review concepts for fuzzy hierarchical evaluation. Then the following sections will introduce the computational process about Fuzzy AHP in detail.

#### *4.1.1. Establishing fuzzy number*

Fuzzy sets are sets whose elements have degrees of membership. Fuzzy sets have been introduced by Zadeh (1965) as an extension of the classical notion of set. In classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition – an element either belongs or does not belong to the set (Liou, Yen, & Tzeng, 2007; Wu & Lee, 2007). The mathematics concept borrowed from Liou et al. (2007).

A fuzzy number $\widetilde{A}$ on $\mathbb{R}$ to be a TFN if its membership function $\mu_{\widetilde{A}}(x):\mathbb{R}\to[0,1]$is equal to following Eq. (1):

$$\mu_{\widetilde{A}}(x)=\begin{cases}(x-L)/(M-L), & L\leqslant x\leqslant M,\\ (U-x)/(U-M), & M\leqslant x\leqslant U,\\ 0, & \text{otherwise}.\end{cases} \tag{1}$$

From the above Eq. (1), the $L$ and $U$ mean the lower and upper bounds of the fuzzy number $\widetilde{A}$, and $M$ is the modal value for $\widetilde{A}$. The TFN can be denoted by $\widetilde{A}=(L,M,U)$. The operational laws of TFNs $\widetilde{A}_1=(L_1,M_1,N_1)$ and $\widetilde{A}_2=(L_2,M_2,N_2)$ are displayed as following Eqs. (2)–(5).

Addition of the fuzzy number $\oplus$

$$\widetilde{A}_1\oplus\widetilde{A}_2=(L_1,M_1,U_1)\oplus(L_2,M_2,U_2)=(L_1+L_2,M_1+M_2,U_1+U_2). \tag{2}$$

Multiplication of the fuzzy number $\otimes$

$$\widetilde{A}_1\otimes\widetilde{A}_2=(L_1,M_1,U_1)\oplus(L_2,M_2,U_2)=(L_1L_2,M_1M_2,U_1U_2)\quad L_i>0,\ M_i>0,\ U_i>0. \tag{3}$$

Subtraction of the fuzzy number $\ominus$

$$\widetilde{A}_1-\widetilde{A}_2=(L_1,M_1,U_1)-(L_2,M_2,U_2)=(L_1-L_2,M_1-M_2,U_1-U_2). \tag{4}$$

Reciprocal of the fuzzy number

$$\widetilde{A}_1^{-1}=(L_1,M_1,U_1)^{-1}=(1/U_1,1/M_1,1/L_1)\quad L_1,M_1,U_1>0. \tag{5}$$

#### *4.1.2. Determining the linguistic variables*

Linguistic variables take on values defined in its term set – its set of linguistic terms. Linguistic terms are subjective categories for the linguistic variable. A linguistic variable is a variable whose values are words or sentences in a natural or artificial language. Here, we use this kind of expression to compare two building Cluster Policy evaluation dimension by nine basic linguistic terms, as "Perfect," "Absolute," "Very good," "Fairly good," "Good," "Preferable," "Not Bad," "Weak advantage" and "Equal" with respect to a fuzzy nine level scale. In this paper, the computational technique is based on the following fuzzy numbers defined by Gumus (2009) in Table 1. Here each membership function (scale of fuzzy number) is defined by three parameters of the symmetric triangular fuzzy number, the left point, middle point and right point of the range over which the function is defined. The use of linguistic variables is currently widespread and the linguistic effect values of Cluster policy alternatives found in this study are primarily used to assess the linguistic ratings given by the evaluators (see Fig. 1).

In addition, linguistic variables are used as a way to measure the performance value of building cluster policy alternative for each criterion as "very good," "good," "fair," "poor" and "very poor". The triangular fuzzy numbers (TFN) is shown in Fig. 2. This Fig. 2 can indicate the membership functions of the expression values. The computational technique is based on the following fuzzy numbers defined by Hsieh, Lu, and Tzeng (2004).

**Table 1**
Membership function of linguistic scale.

| Fuzzy number | Linguistic | Scale of fuzzy number |
|---|---|---|
| 9 | Perfect | (8,9,10) |
| 8 | Absolute | (7,8,9) |
| 7 | Very good | (6,7,8) |
| 6 | Fairly good | (5,6,7) |
| 5 | Good | (4,5,6) |
| 4 | Preferable | (3,4,5) |
| 3 | Not bad | (2,3,4) |
| 2 | Weak advantage | (1,2,3) |
| 1 | Equal | (1,1,1) |

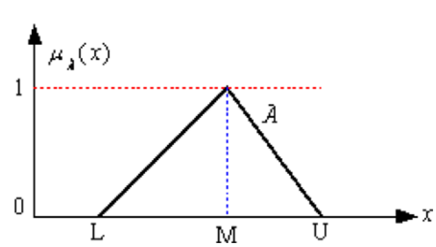


**Fig. 1.** The membership function of the triangular fuzzy number.

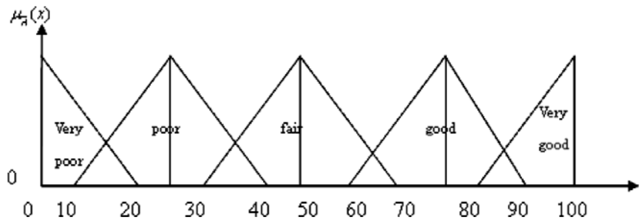


**Fig. 2.** Example of membership function of linguistic variables for measuring the performance value of alternatives.

### 4.1.3. Fuzzy AHP

Then we will briefly introduce that how to carry out the fuzzy AHP in the following sections.

Step1: Construct pair-wise comparison matrices among all the elements/criteria in the dimensions of the hierarchy system. Assign linguistic terms to the pair-wise comparisons by asking which is the more important of each two dimensions, as following matrix $\widetilde{A}$

$$\widetilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \cdots & 1 \end{bmatrix} \tag{6}$$

where $\tilde{a}_{ij} = \begin{cases} \tilde{1},\tilde{2},\tilde{3},\tilde{4},\tilde{5},\tilde{6},\tilde{7},\tilde{8},\tilde{9}, \\ 1, \\ \tilde{1}^{-1},\tilde{2}^{-1},\tilde{3}^{-1},\tilde{4}^{-1},\tilde{5}^{-1},\tilde{6}^{-1},\tilde{7}^{-1},\tilde{8}^{-1},\tilde{9}^{-1}. \end{cases}$

Step 2: To use geometric mean technique to define the fuzzy geometric mean and fuzzy weights of each Criterion by Hsieh et al. (2004)

$$\tilde{r}_i = (\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \cdots \otimes \tilde{a}_{in})^{1/n} = \tilde{r}_i(\tilde{r}_1 \oplus \tilde{r}_2 \oplus \cdots \oplus \tilde{r}_n)^{-1}, \tag{7}$$

where $\tilde{a}_{in}$ is fuzzy comparison value of dimension $i$ to criterion $n$, thus, $\tilde{r}_i$ is geometric mean of fuzzy comparison value of criterion $i$ to each criterion, $\tilde{w}_i$ is the fuzzy weight of the $i$th criterion, can be indicated by a *TFN*, $\tilde{w}_i = (Lw_i, Mw_i, Uw_i)$. The$Lw_i, Mw_i$ and $Uw_i$ stand for the lower, middle and upper values of the fuzzy weight of the $i$th dimension.

### 4.2. Fuzzy multiple dimension decision-making

This study uses this method to evaluate the cluster policy alternatives performance and rank the priority for them accordingly. The following will be the method and procedures of the FMCDM theory.

Step 1: Alternatives measurement. This study applies the linguistic variables to measure the dimension performance. The experts are asked for conduct their subjective judgments and each linguistic variable can be indicated by a TFN within the scale range 0–100 (figure). Every expert identifies their own range of linguistic variable that can indicate the membership functions of expression values of each expert. Then, this work use $\widetilde{E}_{ij}^k$ to determine the fuzzy performance value that expert $k$ towards alternative $i$ under dimension $j$. Moreover, all of the dimension will be indicated by $\widetilde{E}_{ij}^k = (LE_{ij}^k, ME_{ij}^k, UE_{ij}^k)$. Then this work applies the average value to integrate fuzzy judgment values of $m$ experts, and the computational processes are demonstrated by following Eq. (8)

$$\widetilde{E}_{ij} = (1/m) \otimes (\widetilde{E}_{ij}^1 \oplus \widetilde{E}_{ij}^2 \oplus \cdots \oplus \widetilde{E}_{ij}^m), \tag{8}$$

where $\widetilde{E}_{ij}$ is the mean of fuzzy number for each expert, which can be showed by a triangular fuzzy number as $\widetilde{E}_{ij} = (LE_{ij}, ME_{ij}, UE_{ij})$. The value of $LE_{ij}, ME_{ij}$ and $UE_{ij}$ can be solved by following Eq. (9).

$$LE_{ij} = \left(\sum_{k=1}^{m} LE_{ij}^k\right), \quad ME_{ij} = \left(\sum_{k=1}^{m} ME_{ij}^k\right), \quad UE_{ij} = \left(\sum_{k=1}^{m} UE_{ij}^k\right). \tag{9}$$

Step 2: Fuzzy synthetic decision. Then this research integrates the weights of each dimension of driving forces and fuzzy performance of each cluster policy. From the dimension weight vector $\tilde{w}$ and fuzzy performance matrix $\widetilde{E}$, the final fuzzy synthetic decision can be done by following Eq. (10).

$$\widetilde{R} = \widetilde{E} \circ \widetilde{w}, \tag{10}$$

where the $\widetilde{R}$ is the fuzzy number of each alternative, and it can be shown as $\widetilde{R} = (LR_i, MR_i, UR_i)$. The value of $LR_i, MR_i$ and $UR_i$ represent the lower, middle and upper synthetic performance value of each alternative$i$. We can use following Eq. (11) to compute the value

$$LR_i = \sum_{j=1}^{n} LE_{ij} \times Lw_j, \quad MR_i = \sum_{j=1}^{n} ME_{ij} \times Mw_j, \quad UR_i = \sum_{j=1}^{n} UE_{ij} \times Uw_j, \tag{11}$$

Step 3: Ranking the fuzzy performance. Then we should defuzzy of the fuzzy average matrix $\widetilde{A}$. The center of area (COA) defuzzification method is used to determine the best non-fuzzy performance (BNP) value of the fuzzy numbers (Liou et al., 2007). The BNP value of the fuzzy number $\widetilde{R}_i$ can be done by following Eq. (12)

$$\text{BNP}_i = [(UR_i - LR_i) + (MR_i - LR_i)]/3 + LR_i \quad \forall i. \tag{12}$$

According to the results that derived by BNP calculate process, the ranking of each alternative can then proceed.

There are numerous studies that apply fuzzy AHP method to solve different managerial problems. Huang, Chu, and Chiang (2008) adopt a Fuzzy Analytic Hierarchy Process method and utilize crisp judgment matrix to evaluate subjective expert judgments made. Pan (2008) applied fuzzy AHP model for selecting the suitable bridge construction method. Cakir and Canbolat (2008) propose an inventory classification system based on the Fuzzy Analytic Hierarchy Process. Wang and Chen (2008) applied fuzzy linguistic preference relations to construct a pairwise comparison matrix with additive reciprocal property and consistency. Sambasivan and Fei (2008) evaluate the factors and sub-factors critical to the successful implementation of ISO 14001-based environmental management system and benefits. Sharma, Moon, and Bae (2008) used AHP methodology to optimize the selection of delivery network design followed by relevant choices for decision making of Home plus distribution center. Costa, Bana e, and Vansnick (2008) discussed the meaning of the priority vector derived from the principal eigenvalue method used in AHP. Firouzabadi, Khatami, Henson, and Barnes (2008) presented a decision support methodology for strategic selection decisions used a combination of Analytic Hierarchy Process and Zero-One Goal Programming to address the selection problem from the point of view of an individual stakeholder. Wang, Luo, and Hua (2008) showed by examples that the priority vectors determined by the Analytic Hierarchy Process method. Gumus (2009) evaluate hazardous waste transportation firms containing the methods of fuzzy-AHP and TOPSIS. Armillotta (2008) described a computer-based tool for the selection of techniques used in the manufacture of prototypes and limited production runs of industrial products. The underlying decision model based on the AHP methodology, Dagdeviren and Yuksel (2008) presented fuzzy AHP approach to determine the level of faulty behavior risk in work systems. Chen, Tzeng, and Ding (2008) used Fuzzy Analytic Hierarchy Process to determine the weighting of subjective/perceptive judgments for each criterion and to derive fuzzy synthetic utility values of alternatives in a fuzzy multi-criteria decision-making environment. Lin, Wang, Chen, and Chang (2008) proposed a framework that integrates the analytical hierarchy process and the technique for order preference by similarity to ideal solution to assist designers in identifying customer requirements and design characteristics, and help achieve an effective evaluation of the final design solution.

## 5. Empirical evidence from HsinChu Science Park

The cluster is focused on linkages and interdependencies among players in the value chain. It emphasizes the role of technological spillovers and cross-sectoral linkages of dissimilar and complementary firms as major sources of long-term growth. Thus it goes beyond the horizontal networks of firms that operate on the same end-product market and belong to the same industry group, and allows cooperation on aspects such as collective marketing and purchasing (Bonita et al., 2002). Clusters take up the challenge of globalization and liberalization. This requires producing according to international benchmarks of product quality and production flexibility. Then we will briefly introduce the research framework.

### *5.1. Research framework*

Regarding the evaluation of the cluster policies, ten experts were invited to survey five alternatives using the research framework shown in Fig. 3. The 10 experts, including four industrial analysts from industrial Technology Research Institute, four managers of high-tech companies, one professor of management of school and one government representative from Bureau of Urban Development HsinChu City Government. This research framework includes six driving forces, such as factor conditions, local demand conditions, related and supporting industries, firm structure and strategy and rivalry, government support and culture. In addition, there are five alternatives of cluster policy that encompass broker policy, demand side policy, training policy, promotion of international linkage policy and broader framework policy.

The whole hierarchy of accessing the cluster policy can be easily visualized from Fig. 3. After the construction of the hierarchy the different priority weights of each criteria, attributes and alternatives are calculated using the FAHP approach. The comparison of the importance or preference of one criterion, attribute or alternative over another can be done with the help of the questionnaire. The method of calculating priority weights of the different decision alternatives using FAHP is discussed below.

### *5.2. The weights of evaluation dimensions*

We adopt Fuzzy AHP method to evaluate the weights of different driving forces for the growth of industrial cluster. Following the construction of Fuzzy AHP model, it is extremely important that experts fill the judgment matrix. In this study, four industrial analysts from industrial Technology Research Institute, four managers of high-tech companies, one professor of management of school and one government representative from Bureau of Urban Development HsinChu City Government experts are involved.

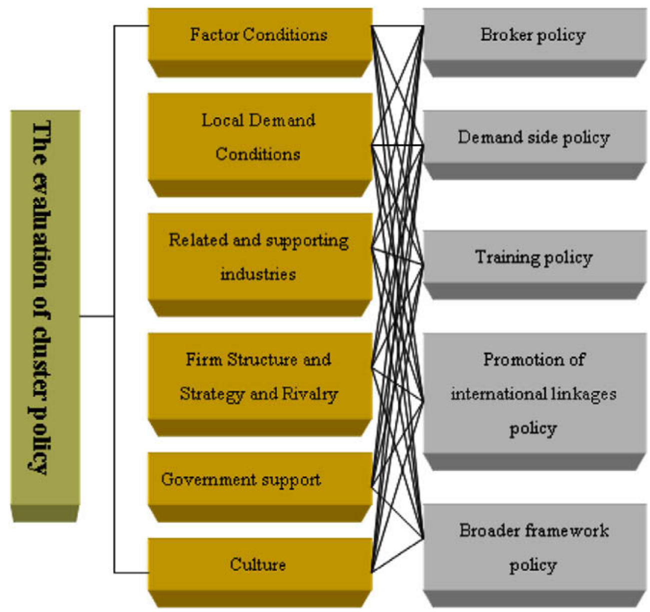


**Fig. 3.** Research framework.

The following section demonstrates the computational procedure of the weights of dimensions.

(1) According to the committee with ten representatives about the relative important of cluster driving forces, then the pair-wise comparison matrices of dimensions will be obtained. We apply the fuzzy numbers defined in Table 2. We transfer the linguistic scales to the corresponding fuzzy numbers (as Appendix B).
(2) Computing the elements of synthetic pair-wise comparison matrix by using the geometric mean method suggested by Buckley (1985) that is: $\tilde{a}_{ij} = (\tilde{a}^1_{ij} \otimes \tilde{a}^5_{ij} \otimes \cdots \otimes \tilde{a}^{10}_{ij})$, for $\tilde{a}_{12}$ as the example:

$$\begin{aligned}\tilde{a}_{12} &= (4,5,6) \otimes (6,7,8) \otimes \cdots \otimes (5,6,7)^{1/10} \\ &= ((4 \times 6 \times \cdots \times 5)^{1/10}, (5 \times 7 \times \cdots \times 7)^{1/10}, (6 \times 8 \cdots \\ &\quad \times 7)^{1/10}) \\ &= (2.4856, 3.408537, 4.340001).\end{aligned}$$

It can be obtained the other matrix elements by the same computational procedure, therefore, the synthetic pair-wise comparison matrices of the five representatives will be constructed as follows matrix $A$:

**Table 2**
The function of linguistic scale.

| Fuzzy number | Linguistic | Scale of fuzzy number |
|---|---|---|
| 9 | Perfect | (8,9,10) |
| 8 | Absolute | (7,8,9) |
| 7 | Very good | (6,7,8) |
| 6 | Fairly good | (5,6,7) |
| 5 | Good | (4,5,6) |
| 4 | Preferable | (3,4,5) |
| 3 | Not Bad | (2,3,4) |
| 2 | Weak advantage | (1,2,3) |
| 1 | Equal | (1,1,1) |

$$A = \begin{array}{c} \\ D1 \\ D2 \\ D3 \\ D4 \\ D5 \\ D6 \end{array}\begin{array}{cccccc} D1 & D2 & D3 & D4 & D5 & D6 \\ 1 & (2.486,3.409,4.340) & (2.512,3.406,4.232) & (1.208,1.650,2.218) & (1.257,1.768,2.126) & (3.110,3.666,4.237) \\ (0.230,0.293,0.402) & 1 & (0.225,0.297,0.384) & (0.227,0.277,0.350) & (0.305,0.381,0.464) & (0.514,0.589,0.670) \\ (0.236,0.294,0.398) & (2.605,3.363,4.445) & 1 & (0.536,0.651,0.821) & (0.732,0.935,1.194) & (1.680,2.273,3.104) \\ (0.483,0.606,0.828) & (2.855,3.605,4.467) & (1.218,1.537,1.866) & 1 & (2.078,2.902,3.778) & (2.414,3.230,4.331) \\ (0.470,0.583,0.796) & (2.153,2.622,3.277) & (0.838,1.070,1.463) & (0.265,0.345,0.481) & 1 & (1.628,2.252,3.140) \\ (0.236,0.273,0.322) & (1.493,1.698,1.946) & (0.322,0.435,0.595) & (0.231,0.310,0.414) & (0.318,0.444,0.614) & 1 \end{array}.$$

(3) To calculate the fuzzy weights of dimensions, the computational procedures are displayed as following parts

$$\begin{aligned}\tilde{r}_1 &= (\tilde{a}_{11} \otimes \tilde{a}_{12} \otimes \tilde{a}_{13} \otimes \tilde{a}_{14} \otimes \tilde{a}_{15} \otimes \tilde{a}_{16})^{1/6} \\ &= (1 \times 2.486 \times \cdots \times 3.110)^{1/6}, \\ &\quad (1 \times 3.409 \times \cdots \times 3.666)^{1/6}, (1 \times 4.340 \times \cdots \times 4.237) \\ &= (1.758, 2.234, 2.676).\end{aligned}$$

Similarly, we can obtain the remaining $\tilde{r}_i$, there are:

$$\begin{aligned}\tilde{r}_2 &= (0.350, 0.419, 0.506), \\ \tilde{r}_3 &= (0.860, 1.053, 1.324), \\ \tilde{r}_4 &= (1.427, 1.777, 2.198), \\ \tilde{r}_5 &= (0.846, 1.041, 1.339), \\ \tilde{r}_6 &= (0.450, 0.550, 0.675).\end{aligned}$$

For the weight of each dimension, they can be done as follows:

$$\begin{aligned}\tilde{w}_1 &= \tilde{r}_1 \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \tilde{r}_3 \oplus \tilde{r}_4 \oplus \tilde{r}_5 \oplus \tilde{r}_6)^{-1} \\ &= (1.758, 2.234, 2.676) \otimes (1/(2.676 + \cdots + 0.675), \\ &\quad 1/(2.234 + \cdots + 0.550), 1/(1.758 + \cdots + 0.450)) \\ &= (0.202, 0.316, 0.470).\end{aligned}$$

We also can calculate the remaining $\tilde{w}_i$, there are:

$$\begin{aligned}\tilde{w}_2 &= (0.040, 0.059, 0.089), \\ \tilde{w}_3 &= (0.099, 0.149, 0.233), \\ \tilde{w}_4 &= (0.164, 0.251, 0.386), \\ \tilde{w}_5 &= (0.097, 0.147, 0.235), \\ \tilde{w}_6 &= (0.052, 0.078, 0.119).\end{aligned}$$

(4) To apply the COA method to compute the BNP value of the fuzzy weights of each dimension: To take the BNP value of the weight of D1 (factor condition) as an example, the calculation process is as follows.

$$\begin{aligned}\text{BNP}_{w_1} &= [(U_{w_1} - L_{w_1}) + (M_{w_1} - L_{w_1})]/3 + L_{w_1} \\ &= [(0.470 - 0.202) + (0.316 - 0.202)]/3 + 0.202 \\ &= 0.329.\end{aligned}$$

Then, the weights for the remaining dimensions can be found as shown in Table 3. Table 3 shows the relative weight of six driving forces of the growth for industrial cluster, which obtained by AHP method. The weights for each driving forces are: Factor Conditions (0.329), Local Demand Conditions (0.063), Related and Supporting Industries (0.160), Firm Structure and Strategy and Rivalry (0.267), Government support (0.160) and Culture (0.083). From the Fuzzy AHP results, we can understand the first two important driving forces for the growth of industrial cluster are factor conditions (0.329) and firm structure, strategy and rivalry (0.267). Moreover, the less important driving force is local demand conditions (0.063).

**Table 3**
Weights of dimensions.

| Dimension | Weights | BNP | Rank |
|---|---|---|---|
| Factor conditions | (0.202, 0.316, 0.470) | 0.329 | 1 |
| Local demand conditions | (0.040, 0.059, 0.089) | 0.063 | 6 |
| Related and supporting industries | (0.099, 0.149, 0.233) | 0.160 | 3 |
| Firm structure, strategy and rivalry | (0.164, 0.251, 0.386) | 0.267 | 2 |
| Government support | (0.097, 0.147, 0.235) | 0.160 | 3 |
| Culture | (0.052, 0.078, 0.119) | 0.083 | 5 |

### 5.3. Estimating the performance

This paper focus on determining the optimal cluster policy; so, we assume that questionnaire have collected completely and will start with building dataset that are collected. The evaluators has their own range for the linguistic variables employed in this study according to their subjective judgments within a scale of 0–100 reveals a degree of variation in their definitions of the linguistic variables (Hsieh, Lu and Tzeng, 2004).

According to Pedrycz (1994) have suggested to a certain theoretically sound motivation behind the common use of triangular membership functions; so, we adopted triangular membership functions to illustrate the fuzzy questionnaire in this paper. For each evaluator with the same importance, this study employs the method of average value to integrate the fuzzy/vague judgment values of different evaluators regarding the same evaluation dimensions.

(1) We had been collected 10 surveyors in the sample, and then we can undertake to construct dataset with fuzzy questionnaire such as Table 4.
(2) Continually, this research calculates the fuzzy performance value of different cluster policies under each driving force. We demonstrate the computational process of Broker policy under the dimension of factor condition.

$$\begin{aligned}\widetilde{E}_{11} &= \left(\left(\sum_{k=1}^{10} LE_{11}^k\right)\Big/10, \left(\sum_{k=1}^{10} ME_{11}^k\right)\Big/10, \left(\sum_{k=1}^{10} UE_{11}^k\right)\Big/10\right) \\ &= (53.2, 60.3, 68.5).\end{aligned}$$

The remainder elements of fuzzy performance values of each criterion of experts for each alternative can be obtained by the same procedure, and it is shown in Table 5.

### 5.4. Ranking the alternatives

From the dimensions weights and average of the three obtained and the average fuzzy performance values of each criterion of experts for each alternative, the final fuzzy synthetic decision can then be calculated. After the fuzzy synthetic decision is processed, the non-fuzzy ranking method is then employed, and finally the fuzzy numbers are changed into non-fuzzy values. Though there

**Table 4**
Subjective cognition results of evaluators towards the five levels of linguistic variables.

| Evaluator | Linguistic variables | | | | |
|---|---|---|---|---|---|
| | Very dissatisfied | Dissatisfied | Medium | Satisfied | Very satisfied |
| 1 | (5,7,12) | (13,25,38) | (37,50,62) | (63,75,88) | (88,93,100) |
| 2 | (5,15,25) | (40,50,60) | (60,70,80) | (70,80,90) | (85,90,100) |
| 3 | (0,10,30) | (30,40,50) | (50,60,70) | (70,80,90) | (90,95,100) |
| 4 | (10,20,35) | (30,40,45) | (50,60,70) | (75,80,85) | (85,90,100) |
| 5 | (0,10,15) | (30,40,45) | (50,60,65 | (70,80,85) | (80,90,100) |
| 6 | (10,25,40) | (40,50,65) | (65,75,80) | (80,85,90) | (85,85,90) |
| 7 | (5,10,20) | (20,30,50) | (55,58,63) | (70,78,86) | (85,90,100) |
| 8 | (45,50,55) | (55,60,65) | (65,70,75) | (75,80,85) | (85,90,95) |
| 9 | (0,20,40) | (30,45,60) | (55,65,75) | (75,85,95) | (90,95,100) |
| 10 | (0,20,40) | (40,50,60) | (60,70,80) | (80,85,90) | (90,95,100) |

Note that item's column in this Table "1" stand for "very dissatisfied", "2" stand for " dissatisfied", "3" stand for "medium", "4" stand for "satisfied", and "5" stand for "very satisfied".

**Table 5**
Average fuzzy performance values of each criterion of experts for each alternative.

| Alternative | | | | | |
|---|---|---|---|---|---|
| Dimension | Broker policy | Demand side policy | Training policy | Promotion of international linkages policy | Broader framework policy |
| Factor conditions | (53.2,60.3,68.5) | (66.3,74.8,82.4) | (64.7,71.8,78.3) | (69.2,68.7,84.8) | (66.3,73.8,80.9) |
| Local demand conditions | (54.3,74.1,71.6) | (71.3,75.8,86.4) | (34.8,64.8,57.3) | (47.8,75.8,67.3) | (54.8,81.3,73.8) |
| Related and supporting industries | (65.8,63.3,81.6) | (67.8,78.8,83.4) | (56.2,48.9,72.5) | (67.3,57.5,83.4) | (74.3,64.5,88.4) |
| Firm structure, strategy and rivalry | (65.8,74.1,82.1) | (66.3,75.3,83.9) | (66.7,74.3,81.8) | (71.3,71.7,88.4) | (76.8,83.3,90.4) |
| Government support | (59.7,68.3,76.0) | (77.3,84.6,91.6) | (71.8,79.8,86.9) | (75.8,83.3,90.4) | (77.3,84.1,91.1) |
| Culture | (53.7,62.3,70.8) | (35.2,45.8,56.0) | (50.7,60.0,70.2) | (58.8,67.5,77.3) | (53.7,63.3,72.3) |

are methods to rank these fuzzy numbers, this study has employed COA to determine the BNP value, which is used to rank the evaluation results of each cluster policy alternative. To take the fuzzy synthetic decision value of broker policy under weights as an example, we can obtain this value as follows:

$$\begin{aligned}\widetilde{R}_1 &= (LR_1, MR_1, UR_1)\\ &= (53.2\times 0.202+\cdots+53.7\times 0.052),(60.3\times 0.316+\cdots\\ &\quad +62.3\times 0.078),(68.5\times 0.470+\cdots+70.8\times 0.119)\\ &= (38.73, 66.36, 115.56),\end{aligned}$$

$$\widetilde{R}_2 = (43.09, 74.77, 126.44),$$
$$\widetilde{R}_3 = (40.48, 68.86, 119.16),$$
$$\widetilde{R}_4 = (44.57, 70.26, 129.85),$$
$$\widetilde{R}_5 = (45.74, 75.94, 130.10).$$

Continually, we determine the BNP value as follows.

$$\mathrm{BNP}_1 = [(115.56-38.77)+(66.36-38.77)]/3+38.77 = 73.55.$$

In the meantime, we also find out the BNP values of other alternatives and displayed in Table 6. From the alternative evaluation results in Table 6, the most two appropriate cluster policies are broader framework policy and promotion of international linkages policy.

**Table 6**
Performance value and ranking of different policy tool.

| | | $\mathrm{BNP}_i$ | Ranking |
|---|---|---|---|
| Broker policy | (38.73,66.36,115.56) | 73.55 | 5 |
| Demand side policy | (43.09,74.77,126.44) | 81.43 | 3 |
| Training policy | (40.48,68.86,119.16) | 76.17 | 4 |
| Promotion of international linkages policy | (44.57,70.26,129.85) | 81.56 | 2 |
| Broader framework policy | (45.74,75.94,130.10) | 83.93 | 1 |

### 5.5. Discussion

The committee remarks that the "factor conditions" is a critical driving force for the growth of industrial cluster, too. The factor conditions mean the specific factors. They are more difficult to duplicate. This leads to a competitive advantage, because if other firms cannot easily duplicate these factors, they are valuable. Based on our definition of factor conditions, specialized factors of production are skilled labor, capital and information infrastructure. The main factor conditions include entrepreneurship, venture capital, Science Park and incubators for the growth of the industrial cluster.

Taiwan's venture capital industry is the third most active venture capital market in the world, ranking behind the US and Israel. The annual growth rate in the number of Taiwan venture capital companies and the growth rate of venture capital investment exceeded 50% in 1997 and 1998, a clear indication of the rapid development of Taiwan's venture capital sector over the last few years (Chang & Shih, 2005). On the other hand, since 1996, the Small and Medium Enterprise (SME) Administration of the Ministry of Economic Affairs of Taiwan has been using the SME Development Fund to encourage both public agencies and private sectors to set up SME incubation centers in Taiwan (Chen, 2007). A total of 79 SME incubators have been established in northern, central, southern and eastern Taiwan. Finally, in the Taiwanese policies we can see that the role of government as a direct provider (as opposed to facilitator) is emphasized; for example, it establishes research institutes to directly conduct a range of research that then becomes available to local industry. These institutes, such as the Industrial Technology Research Institute (ITRI), Technological Information Center, and National Science Council (NSC), conduct research on a large scale and undertake studies into the feasibility of industrializing new technology. Although it tries to link universities via conferences, in effect the Taiwanese government is focused on providing the tools of innovation, i.e., technically educated students, government funded research, training, and information (Chen, 2007).

From our research result, it also indicates that the ''Firm Structure, Strategy and Rivalry'' is another important diving force of the growth for industrial cluster. The research outcome also accords with the previous studies. Porter (1998) believes that the clustering of industry will lead towards vigorous competition that will result in the rapid development of skilled workers, the creation of related technological industries, and specialized infrastructure that gives each firm within the cluster a competitive advantage. The rivalry for final goods stimulates the emergence of an industry that provides specialized intermediate goods. Keen domestic competition leads to more sophisticated consumers who come to expect upgrading and innovation. Finally, we also find out that local demand condition and culture rank last priorities among these dimensions. The main reason why local demand condition and culture are the relatively weak driving forces of Taiwan's industrial clustering should lie in that, Taiwan's industry is mainly export oriented and more and more globalized due to its Original Design Manufacturing (ODM) mode. Weaker culture may therefore result from the gradual spread of higher internationalization within the science park. However according to our observation there is no much blending of diverse cultures, tending to be a challenging obstacle to successful collaboration within the cluster.

Furthermore, this research bases on these six driving forces to access the cluster policies. From our research results, we can understand that the promotion of international linkages policy and Broader framework policy rank the fist two important policy tool for the cluster growth.

Promotion of international linkages policy means that the elimination of trade barriers and strengthening of transport and communication systems, along with the harmonization of market regulations have greatly improved conditions of resource flows and enhanced specialization of value chain across national borders. Flows of outward FDI typically enable an economy to induce growth in areas marked by relatively high productivity. Outward FDI amplifies the competitive position of domestic firms, including through enhanced international specialization of their operations, allowing better market access, adaptation of products to foreign markets, and tapping into low cost resources for standardized production (Hiratsuka, 2006). Industries making outward foreign investment because of acquirement of land, capital utilization, and overcome trade barrier think benefit on expanding their domestic production scale. What are the effects of outward foreign investment that outward investment imposes on the growth path of home economies in Taiwan? While outward investment roared at an average annual 62% for the past 25 years, income (GDP), employment, wage, and domestic investment had also increased quite steadily. The average annual growth rates were 6% for GDP, 2% for employment, 5% for wage, and 5% for domestic investment over the same period (Li & Roe, 2008).

In addition, broader framework policies focus on an over-riding playing field marked by effective and consistent rules for inter-actor transactions. Relevant framework conditions include macroeconomic stability, well-functioning product market, factor market (labor and financial markets), education systems, and physical, institutional and judicial infrastructure, including a governance system that is able to sustain effective and consistent playing rules for innovation, the existence of an appropriate communications and transport infrastructure. According to the US-based business research group Business Environment Risk Intelligence (BERI), that evaluates the investment environment of over 50 countries, Taiwan ranked 6th among the world's lowest risk countries, behind Switzerland, Singapore, the Netherlands, Japan, and Norway in 2007 (Wong, 2007). The ranking of BERI is the result of assessments of operating conditions, political risk, and the foreign exchange/external account position for about 50 important countries. In 2007, Taiwan ranked 3rd among the 50 investigated countries in terms of operation risk, 5th in terms of foreign exchange/external account position and 15th globally on the political risk factor (as Appendix C). Furthermore, According to the Economist Intelligence Unit (EIU) of the London based Economist. Taiwan ranks 19th globally out of 82 countries and 3rd in Asia (behind Singapore and Hong Kong) for its business environment. The business ranking model takes ten criteria for the business environment into account, covering political environment, the macroeconomic environment, market opportunities, policy towards free enterprise and competition, policy towards foreign investment, foreign trade and exchange controls, taxes, financing, the labor market and infrastructure. A recent research of the Economist Intelligence Unit ranked Taiwan 17th globally for e-readiness (Japan was ranked 18th and Korea 16th), indicating the governments' commitment in pushing digital development, and continued progress in adoption of broadband and other advanced infrastructure. Also in the Global Competitiveness Report 2007–2008 of the World Economic Forum, Taiwan gets a high ranking: it is ranked 14th globally in terms of global competitiveness (Wong, 2007).

In facing economic challenge from the international community, Taiwan's government has been opening up the domestic monetary market. This has cultivated an investment environment for foreign businesses to pull together multi-national capital resources. To make transmission of funding more convenient, the government has allowed international financial firms to set up bases in Taiwan, therefore enabling transnational enterprises establish operations in Mainland China and throughout Southeast Asia, while having a strong foothold in Taiwan. Taiwan is now a convenient operational hub in the Asia–Pacific region, due to its strategic geographic location, as well as its well-developed infrastructure, characterized by the sound transportation system, fully functional ports and harbors, and free-flow customs system.

Huang (2008) suggests that Taiwan government should implement pre-program and post-program performance evaluation mechanism to avoid poor investment. The primary task is to reconstruct a practical evaluation mechanism for project prioritization. We need to adopt the ''Value for Money'' approach right away. The method estimates the investment effect of the government in different phases qualitatively and quantitatively as basis for prioritizing investment projects, the process continues into the operational phases of the infrastructure project in order to keep the public informed of the investment returns (Huang, 2008). In addition, Huang (2008) also advises that Taiwan Government should integrate roles of government agencies and replace political considerations with professional reasoning. We need to mitigate partisan conflicts, improve the quality and efficiency of the justice system, enhance supervision and audit functions and perfect the public policy debate mechanism, such as public hearings. Only in so doing will we should establish a sound infrastructure program audit mechanism and promote various projects that are free from futile disputes (Huang, 2008).

## 6. Conclusion and further work

Carroll and Reid (2004) said that clustering brings a variety of benefits to firms and the local economy. They believe that cluster-based economic development represents an opportunity for industries in our region to reach unprecedented levels of competitiveness. Industrial cluster provides sourcing companies with a greater depth to their supply chain and allows for the potential of inter-firm learning and co-operation. Clusters also give firms the ability to draw together complementary skills in order to bid for large contracts that as individual units they would be unable to successfully compete.

The aim of this research is to construct a fuzzy AHP model to evaluate different cluster policies and to support the selection of priority mix that is efficient. In the performance evaluation of driving forces for the industrial cluster including factor conditions, local demand conditions, related and supporting industries, firm structure and strategy and rivalry, government support and culture. These factors are to generate a final evaluation ranking for priority among these cluster policies of the proposed model. The importance of the dimensions is evaluated by experts, and the uncertainty of human decision-making is taken into account through the fuzzy concept.

From the proposed method, fuzzy AHP, we find out the first two important driving forces for the growth of industrial cluster are factor conditions and firm structure and strategy and rivalry. On the other hand, local demand condition and culture rank last priorities among these dimensions.

However, this research has some limitations. This HsinChu Science Park is our research objective. The different Science Park and different countries have their features and characteristics. Therefore, the comparison among different Science Parks and Countries is a meaningful and interesting research for industrial cluster.

## Appendix A. WEF ranking of the competitiveness of industrial clusters

| | 2007–2008 | | 2006–2007 | | 2005–2006 | |
|---|---|---|---|---|---|---|
| | Score | Global ranking | Score | Global ranking | Score | Global ranking |
| **Taiwan** | **5.7** | **1** | **5.52** | **1** | **5.39** | **2** |
| United States | 5.3 | 2 | 5.22 | 2 | 5.19 | 4 |
| South Korea | 5.1 | 3 | 4.19 | 31 | 4.38 | 21 |
| Singapore | 5.1 | 4 | 4.92 | 7 | 5.15 | 6 |
| England | 4.8 | 9 | 5.06 | 4 | 4.63 | 14 |
| Germany | 4.8 | 10 | 4.90 | 8 | 4.45 | 17 |
| Finland | 4.8 | 11 | 5.07 | 3 | 5.33 | 3 |
| Japan | 4.7 | 12 | 4.33 | 27 | 5.46 | 1 |
| Switzerland | 4.7 | 13 | 4.67 | 15 | 4.31 | 23 |
| Hong Kong | 4.7 | 14 | 4.75 | 12 | 4.68 | 11 |
| Italy | 4.5 | 21 | 3.19 | 85 | 5.16 | 5 |

Chen (2007).

## Appendix B. Linguistic scales of each expert

$$\begin{matrix} & D1 & D2 & D3 & D4 & D5 & D6 \\ D1 & 1 & \tilde{5} & \tilde{6} & \tilde{4} & \tilde{6} & \tilde{7} \\ D2 & \tilde{5}^{-1} & 1 & \tilde{2} & \tilde{2}^{-1} & \tilde{2} & \tilde{3} \\ D3 & \tilde{6}^{-1} & \tilde{2}^{-1} & 1 & \tilde{3}^{-1} & \tilde{2} & \tilde{3} \\ D4 & \tilde{4}^{-1} & \tilde{2} & \tilde{3} & 1 & \tilde{6} & \tilde{5} \\ D5 & \tilde{6}^{-1} & \tilde{2}^{-1} & \tilde{2}^{-1} & \tilde{6}^{-1} & 1 & \tilde{3} \\ D6 & \tilde{7}^{-1} & \tilde{3}^{-1} & \tilde{3}^{-1} & \tilde{5}^{-1} & \tilde{3}^{-1} & 1 \end{matrix}$$

$$\begin{matrix} & D1 & D2 & D3 & D4 & D5 & D6 \\ D1 & 1 & \tilde{7} & \tilde{3} & \tilde{3} & \tilde{7} & \tilde{1} \\ D2 & \tilde{7}^{-1} & 1 & \tilde{3}^{-1} & \tilde{1} & \tilde{3} & \tilde{7} \\ D3 & \tilde{3}^{-1} & \tilde{3} & 1 & \tilde{4} & \tilde{7} & \tilde{8} \\ D4 & \tilde{3}^{-1} & \tilde{1}^{-1} & \tilde{4}^{-1} & 1 & \tilde{7} & \tilde{8} \\ D5 & \tilde{7}^{-1} & \tilde{3}^{-1} & \tilde{7}^{-1} & \tilde{7}^{-1} & 1 & \tilde{5} \\ D6 & \tilde{1}^{-1} & \tilde{7}^{-1} & \tilde{8}^{-1} & \tilde{8}^{-1} & \tilde{5}^{-1} & 1 \end{matrix}$$

$$\begin{matrix} & D1 & D2 & D3 & D4 & D5 & D6 \\ D1 & 1 & \tilde{2} & \tilde{3} & \tilde{4} & \tilde{2} & \tilde{8} \\ D2 & \tilde{2}^{-1} & 1 & \tilde{7}^{-1} & \tilde{7}^{-1} & \tilde{6}^{-1} & \tilde{8}^{-1} \\ D3 & \tilde{3}^{-1} & \tilde{7} & 1 & \tilde{1} & \tilde{2} & \tilde{2}^{-1} \\ D4 & \tilde{4}^{-1} & \tilde{7} & \tilde{1}^{-1} & 1 & \tilde{2} & \tilde{2}^{-1} \\ D5 & \tilde{2}^{-1} & \tilde{6} & \tilde{2}^{-1} & \tilde{2}^{-1} & 1 & \tilde{2}^{-1} \\ D6 & \tilde{8}^{-1} & \tilde{8} & \tilde{2} & \tilde{2} & \tilde{2} & 1 \end{matrix}$$

$$\begin{matrix} & D1 & D2 & D3 & D4 & D5 & D6 \\ D1 & 1 & \tilde{2} & \tilde{3} & \tilde{4} & \tilde{2} & \tilde{8} \\ D2 & \tilde{2}^{-1} & 1 & \tilde{7}^{-1} & \tilde{7}^{-1} & \tilde{6}^{-1} & \tilde{8}^{-1} \\ D3 & \tilde{3}^{-1} & \tilde{7} & 1 & \tilde{1} & \tilde{2} & \tilde{2}^{-1} \\ D4 & \tilde{4}^{-1} & \tilde{7} & \tilde{1}^{-1} & 1 & \tilde{2} & \tilde{2}^{-1} \\ D5 & \tilde{2}^{-1} & \tilde{6} & \tilde{2}^{-1} & \tilde{2}^{-1} & 1 & \tilde{2}^{-1} \\ D6 & \tilde{8}^{-1} & \tilde{8} & \tilde{2} & \tilde{2} & \tilde{2} & 1 \end{matrix}$$

$$\begin{matrix} & D1 & D2 & D3 & D4 & D5 & D6 \\ D1 & 1 & \tilde{3} & \tilde{2} & \tilde{2} & \tilde{2} & \tilde{5}^{-1} \\ D2 & \tilde{3}^{-1} & 1 & \tilde{4}^{-1} & \tilde{5}^{-1} & \tilde{5}^{-1} & \tilde{1} \\ D3 & \tilde{2}^{-1} & \tilde{4} & 1 & \tilde{3} & \tilde{1} & \tilde{2} \\ D4 & \tilde{2}^{-1} & \tilde{5} & \tilde{3}^{-1} & 1 & \tilde{2} & \tilde{2} \\ D5 & \tilde{2}^{-1} & \tilde{5} & \tilde{1}^{-1} & \tilde{2}^{-1} & 1 & \tilde{2} \\ D6 & \tilde{5} & \tilde{1}^{-1} & \tilde{2}^{-1} & \tilde{2}^{-1} & \tilde{2}^{-1} & 1 \end{matrix}$$

$$\begin{matrix} & D1 & D2 & D3 & D4 & D5 & D6 \\ D1 & 1 & \tilde{3}^{-1} & \tilde{1} & \tilde{2} & \tilde{8} & \tilde{7} \\ D2 & \tilde{3} & 1 & \tilde{2} & \tilde{2} & \tilde{7} & \tilde{6} \\ D3 & \tilde{1}^{-1} & \tilde{2}^{-1} & 1 & \tilde{2}^{-1} & \tilde{7} & \tilde{7} \\ D4 & \tilde{2}^{-1} & \tilde{2}^{-1} & \tilde{2} & 1 & \tilde{7} & \tilde{6} \\ D5 & \tilde{8}^{-1} & \tilde{7}^{-1} & \tilde{7}^{-1} & \tilde{7}^{-1} & 1 & \tilde{3}^{-1} \\ D6 & \tilde{7}^{-1} & \tilde{6}^{-1} & \tilde{7}^{-1} & \tilde{6}^{-1} & \tilde{3} & 1 \end{matrix}.$$

$$\begin{matrix} & D1 & D2 & D3 & D4 & D5 & D6 \\ D1 & 1 & \tilde{6} & \tilde{6} & \tilde{7} & \tilde{4} & \tilde{4} \\ D2 & \tilde{6}^{-1} & 1 & \tilde{5}^{-1} & \tilde{6}^{-1} & \tilde{8}^{-1} & \tilde{8}^{-1} \\ D3 & \tilde{6}^{-1} & \tilde{5} & 1 & \tilde{3}^{-1} & \tilde{4}^{-1} & \tilde{4}^{-1} \\ D4 & \tilde{7}^{-1} & \tilde{6} & \tilde{3} & 1 & \tilde{2}^{-1} & \tilde{3} \\ D5 & \tilde{4}^{-1} & \tilde{8} & \tilde{4} & \tilde{2} & 1 & \tilde{3} \\ D6 & \tilde{4}^{-1} & \tilde{8} & \tilde{4} & \tilde{3}^{-1} & \tilde{3}^{-1} & 1 \end{matrix}$$

$$\begin{matrix} & D1 & D2 & D3 & D4 & D5 & D6 \\ D1 & 1 & \tilde{7} & \tilde{3} & \tilde{1} & \tilde{1} & \tilde{7} \\ D2 & \tilde{7}^{-1} & 1 & \tilde{7}^{-1} & \tilde{7}^{-1} & \tilde{7}^{-1} & \tilde{1} \\ D3 & \tilde{3}^{-1} & \tilde{7} & 1 & \tilde{1} & \tilde{3}^{-1} & \tilde{7} \\ D4 & \tilde{1}^{-1} & \tilde{7} & \tilde{1}^{-1} & 1 & \tilde{1} & \tilde{7} \\ D5 & \tilde{1}^{-1} & \tilde{7} & \tilde{3} & \tilde{1}^{-1} & 1 & \tilde{7} \\ D6 & \tilde{7}^{-1} & \tilde{1}^{-1} & \tilde{7}^{-1} & \tilde{7}^{-1} & \tilde{7}^{-1} & 1 \end{matrix}$$

$$\begin{matrix} & D1 & D2 & D3 & D4 & D5 & D6 \\ D1 & 1 & \tilde{6} & \tilde{6} & \tilde{6}^{-1} & \tilde{7}^{-1} & \tilde{5} \\ D2 & \tilde{6}^{-1} & 1 & \tilde{6}^{-1} & \tilde{6}^{-1} & \tilde{8}^{-1} & \tilde{7}^{-1} \\ D3 & \tilde{6}^{-1} & \tilde{6} & 1 & \tilde{7}^{-1} & \tilde{8}^{-1} & \tilde{5} \\ D4 & \tilde{6} & \tilde{6} & \tilde{7} & 1 & \tilde{6} & \tilde{7} \\ D5 & \tilde{7} & \tilde{8} & \tilde{8} & \tilde{6}^{-1} & 1 & \tilde{8} \\ D6 & \tilde{5}^{-1} & \tilde{7} & \tilde{5}^{-1} & \tilde{7}^{-1} & \tilde{8}^{-1} & 1 \end{matrix}$$

$$\begin{matrix} & D1 & D2 & D3 & D4 & D5 & D6 \\ D1 & 1 & \tilde{6} & \tilde{6} & \tilde{6}^{-1} & \tilde{7}^{-1} & \tilde{5} \\ D2 & \tilde{6}^{-1} & 1 & \tilde{6}^{-1} & \tilde{6}^{-1} & \tilde{8}^{-1} & \tilde{7}^{-1} \\ D3 & \tilde{6}^{-1} & \tilde{6} & 1 & \tilde{7}^{-1} & \tilde{8}^{-1} & \tilde{5} \\ D4 & \tilde{6} & \tilde{6} & \tilde{7} & 1 & \tilde{6} & \tilde{7} \\ D5 & \tilde{7} & \tilde{8} & \tilde{8} & \tilde{6}^{-1} & 1 & \tilde{8} \\ D6 & \tilde{5}^{-1} & \tilde{7} & \tilde{5}^{-1} & \tilde{7}^{-1} & \tilde{8}^{-1} & 1 \end{matrix}$$

## Appendix C. BERI's global investment rankings (April 1, 2007)

| Country | Overall investment environment | | | Operations risk | | Political risk | | Remittance and repatriation factor | |
|---|---|---|---|---|---|---|---|---|---|
| | Score | Rank | Grade | Score | Rank | Score | Rank | Score | Rank |
| Switzerland | 82 | 1 | 1A | 79 | 1 | 77 | 1 | 90 | 2 |
| Singapore | 79 | 2 | 1A | 76 | 2 | 76 | 2 | 86 | 4 |
| Holland | 75 | 3 | 1A | 71 | 5 | 67 | 6 | 87 | 3 |
| Japan | 74 | 4 | 1B | 66 | 13 | 61 | 13 | 96 | 1 |
| Norway | 73 | 5 | 1B | 70 | 6 | 68 | 4 | 82 | 6 |
| Taiwan | 72 | 6 | 1A | 72 | 3 | 59 | 15 | 85 | 5 |
| Germany | 71 | 7 | 1A | 69 | 9 | 62 | 10 | 82 | 6 |
| Austria | 69 | 8 | 1A | 70 | 6 | 70 | 3 | 67 | 15 |
| Belgium | 67 | 9 | 1B | 72 | 3 | 56 | 20 | 73 | 8 |
| United States | 66 | 10 | 1A | 70 | 6 | 65 | 8 | 62 | 20 |

*Source*: Wong (2007).

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