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Indicators of Entrepreneurial University: Fuzzy AHP and Fuzzy TOPSIS Approach

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Abstract The phenomenon of entrepreneurial universities has received considerable attention over the last decades. An entrepreneurial orientation by academia can lead to innovative and sustainable products and research mobilization which help in putting regions and nations in an advantageous position in emerging knowledge-intensive fields of economic activity. Many empirical researches focused on entrepreneurial orientation of university students, but study on antecedents and criteria of the entrepreneurial universities is scarce. The main contribution of this paper is providing a comprehensive criteria set for evaluation of entrepreneurial universities. In this context, environmental and internal factors of entrepreneurial universities were identified based on literature review and survey. Twelve academics and managers have participated in this study by weighing the criteria and scoring alternatives. Society, in particular, higher education institutions, and universities can use the results for creation of new businesses and spin-offs. Data was analyzed by fuzzy analytic hierarchy process (FAHP) and fuzzy technique for order preferences by similarity to ideal solution (FTOPSIS).

Keywords Entrepreneurial university · Environmental factors · Internal factors · Fuzzy AHP · Fuzzy TOPSIS

Introduction

An entrepreneurial society refers to places where knowledge-based entrepreneurship has emerged as a driving force for economic growth, employment creation, and competitiveness in global markets (Audretsch 2007). Universities have frequently been regarded as key institutions in processes of social and intellectual change and development (Payumo et al. 2013). Universities have emerged as central actors in the

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knowledge-based economy and are expected to play an active role in promoting technological change and innovation (Bramwell and Wolfe 2008). The prominence of knowledge as a valuable resource for economic advantage has prompted a shift in expectations of universities to include commercialization of research alongside the traditional activities of teaching and basic research. Consequently, universities are encouraged to become more “entrepreneurial” (Mowery and Shane 2002), requiring changes in their culture, governance, and administration (Todorovic et al. 2011).

Today, universities are important hubs of the international “knowledge economies,” serving to provide systematic and formal knowledge in a range of disciplines, teaching an increasingly qualified workforce, and collaborating with industry in a variety of joint ventures (Frank & Meyer 2007). The notion of the entrepreneurial university has been a perennial issue in innovation management research and higher education policy research during recent decades (Styhre and Lind 2010). A university that embraces its role within the triple helix model (the university-industry-government relations) and adopts the mission of contributing to regional/national development is referred to as an “entrepreneurial university”. As defined by Etzkowitz et al. (2000), an entrepreneurial university is any university that undertakes entrepreneurial activities “…with the objective of improving regional or national economic performance as well as the university’s financial advantage and that of its faculty” (Philpott et al. 2011).

An entrepreneurial university plays an important role in realizing economic innovations and increasing global competitiveness and social welfare. Government needs to stimulate entrepreneurship education and encourage development of entrepreneurial universities (Alexander and Evgeniy 2012). Academics and graduates produce cutting-edge science, new ideas, knowledge, and university-based innovations that can be the major drivers of economic and social development, resulting in increased research expenditures, intellectual property rights (IPR) filings, commercialization agreements, and start-ups based on university inventions (“initiated” as well as “still in active business”. Payumo et al. (2013) demonstrates that pursuing the goal of becoming an entrepreneurial university requires a national legal framework, research budget, and right mix of policies, people, processes, and products.

Although more attention is devoted on entrepreneurial university definition and its dimensions and outcomes, but, few empirical studies have highlighted the importance of environmental and internal factors that conditioned the development of entrepreneurial universities with the teaching, research, and entrepreneurial missions that they need to achieve. This paper aims to contribute to a better understanding of the most critical factors that conditioned these missions and, to this end, applying fuzzy analytic hierarch process (FAHP) for prioritizing critical factors and fuzzy technique for order preferences by similarity to ideal solution (FTOPSIS) for ranking alternative universities with regard to their entrepreneurialism.

The remainder of this paper is organized as follows. Entrepreneurial university and its success factors and barriers are explained in “Literature Review” section. Then, in “Research Methodology” section, fuzzy AHP and fuzzy TOPSIS methods are introduced. In “Empirical Study” section, a numerical example is given, and the results are gained and analyzed. And finally, “Conclusion” section concludes the paper.

Literature Review

The Role of Entrepreneurial Universities in Economic Systems

The interaction between innovation, entrepreneurship, and regional economic development has become a central theme in many policy circles. Besides the presence of entrepreneurs and established companies, much emphasis has been placed on the role of knowledge-generating institutions (such as universities and research laboratories) and of policy makers (Looy et al. 2011). Indeed, now more than ever, universities are moving to the center of society's knowledge production system. Universities contribute to the R&D capability of an economy in a variety of ways including the production of appropriately skilled human capital, the transfer of technology from academia to industry, the creation of frame-breaking basic knowledge, and the generation of spin-out companies that locate in the surrounding territories (Philpott et al. 2011).

In this context, the entrepreneurial university plays an important role as both a knowledge producer and a disseminating institution. Therefore, an entrepreneurial university could be defined as a survivor of competitive environments with a common strategy oriented to being the best in all its activities (e.g., having good finances, selecting good students and teachers, producing quality research) and tries to be more productive and creative in establishing links between education and research (Kirby 2005). Entrepreneurial universities perform wide-range activities such as creation of a technology park, spin-off firm formation, patenting and licensing, contract research, industry training courses, consulting, grantsmanship, publishing academic results, and producing highly qualified graduates (Philpott et al. 2011).

The entrepreneurial university has the ability to generate a focused strategic direction, both in formulating academic goals and in translating knowledge produced within the university into economy (Etzkowitz 2003). Despite industrial and academic systems at varying stages of development, governments in virtually all parts of the world are focusing on the potential of the university as a resource to enhance innovation environments and create a regime of science-based economic development (Etzkowitz et al. 2000). Consequently, an entrepreneurial university is not only a promoter of multiple support measures for entrepreneurship but is also a developer of administrative techniques, strategies, or competitive postures (Antoncic and Hisrich 2001). Based on this, entrepreneurial universities are involved in partnerships, networks, and other relationships with public and private organizations that are an umbrella for interaction, collaboration, and cooperation, and among the core elements of a national innovation system, many different interactions may exist (Inzelt 2004). This means that the entrepreneurial university implements several strategies and new institutional configuration to work together with the government and industries to facilitate the generation and exploitation of knowledge and technology (Leydesdorff and Meyer 2003).

Collaborations between industry and universities are organized using many different forms. In their review of the entrepreneurial activities of universities, Louis et al. (1989) identify five different forms of entrepreneurial activities, namely (1) large-scale science projects, (2) earning supplemental incomes, (3) gaining industry support for university research, (4) obtaining patents and generating trade secrets, and (5) commercialization, i.e., generating or holding equity in private companies based on a faculty member's own research (Styhre and Lind 2010).

Most entrepreneurial universities have adopted new organizational structures and incentive policies to raise awareness among students and staff (such as specialized professorships, entrepreneurship courses, incorporating entrepreneurs into university curricula, and supporting graduates in their start-up activities (Tijssen 2006).

Lam (2007) refers to such individuals within the university system as "entrepreneurial professors," individuals capable of engaging in both Mode 1 research governed by theoretical and paradigmatic research interests and Mode 2 research aimed at coproducing knowledge that is both theoretically solid and practically relevant. Entrepreneurial aspects such as opportunity identification, risk taking, and resource mobilization have been highlighted as critical success factors for academic spin-offs, where entrepreneurial behavior is believed to stimulate growth and economic performance (Walter et al. 2006). One may also assume that the nature of the knowledge-generating processes, and the organizational structure in which they take place, changes significantly as IRR develops towards commercialization of knowledge-based products and services. This "mind to market' trajectory leading to genuine academic entrepreneurship, i.e., launching or organizing a new enterprise, can be modeled in the following three phases of development model:

Phase 1. Application-oriented/science-driven
Phase 2. Product-oriented/utility-driven
Phase 3. Business-oriented/market-driven (Tijssen 2006).

Towards the Entrepreneurial University

The shift towards the "entrepreneurial university" is still in its early stage. To evolve to an entrepreneurial university needs not only university-industry linkages but also high-tech entrepreneurship such as firm formation (start-ups). The first step to an entrepreneurial university is to commit itself from industry-university collaboration to university-industry collaboration. "Steeple excellence" strategy is good for a university, which has limited research resources and fund for entrepreneurship (Zhou 2008).

Also, given the growing global interest on the university's role towards promoting sustainability, an increasing number of universities are committing themselves to sustainability (Nejati and Nejati 2013). Sustainable entrepreneurs seem to combine the best of both worlds, that is, initiating those activities and processes that lead to the identification, evaluation, and exploitation of profitable business opportunities (i.e., entrepreneurship) while contributing to sustainable development (Lans et al. 2014).

Etzkowitz et al. (2000) explained the mechanism and emergent structures for the development of Entrepreneurial Universities and identified four formal process, namely (i) internal transformation that includes a revision of existing tasks, (ii) trans-institutional impact with projects that help to achieve stabilization, (iii) interface process where a centralized institution becomes decentralized, and (iv) recursive effects with the collaboration of trilateral organizations. The Entrepreneurial University model proposed by Etzkowitz (2004) was integrated by a set of five inter-related formal factors, namely capitalization of knowledge, interdependence with the industry and government, other institutional spheres, hybrid organizational forms, and renovation in time. Later, Kirby (2005) has proposed seven strategic actions intended to promote an enterprise culture in universities. The factors that have been identified as formal are strategic actions related with the organization, endorsement, incorporation, implementation, and communication. The factors identified as informal are related to promotion, recognition and reward, and endorsement.

There are many factors that decide entrepreneurial success, such as cultural tradition, practice base, strong needs from local industry development, productive academic results available to be capitalized, and emergence of excellent entrepreneurs (Zhou 2008). Kuratko et al. (2014) identified the following five specific dimensions that are important determinants of an environment conducive to entrepreneurial behavior: (1) top management support, (2) work discretion/autonomy, (3) rewards/reinforcement, (4) time availability, and (5) organizational boundaries. O'Shea et al. (2008) consider the anatomy of an entrepreneurial university and specifically MIT. Finally, they conclude that these elements are of paramount importance in the anatomy of an entrepreneurial university: human capital resources, financial resources, physical resources, commercial resources, status and prestige, networks and alliances, and localization. Todorovic et al. (2011) by an exploratory factor analysis found that university entrepreneurial orientation consists of the following four dimensions: research mobilization, unconventionality, industry collaboration, and university policies. Turró et al. (2013) classified entrepreneurial university factors to informal factors as entrepreneurial culture and credit and formal ones as media impact and procedures. Finally, based on Guerrero and Urbano (2010), the criteria to measure the outcomes of entrepreneurial university suggest the following:

- Formal factors—entrepreneurial organizational and governance structure, support measures for entrepreneurship, and entrepreneurship education.
- Informal factors—university community's attitudes towards entrepreneurship, entrepreneurial teaching methodologies, role models, and reward system.
- Resources—human capital, financial, physical, and commercial.
- Capabilities—status and prestige, networks and alliances, and localization.

Ni-Di and Yi (2010) used fuzzy analytic hierarchy process for evaluating the entrepreneurial capacity of college students. They pointed out that four critical evaluation criteria of this problem are personal characteristics, personal qualities, personal abilities, and environment. Wu et al. (2012) used a hybrid multiple criteria decision-making model to weigh the performance evaluation indices for higher education based on the official performance evaluation structure. Huang et al. (2010) proposed a non-additive fuzzy integral-based fuzzy multiple criteria decision making for assisting decision makers to evaluate the location global R&D center. Rezaei et al. (2013) used FAHP to evaluate the entrepreneurship orientation (EO) of 59 small- to medium-sized enterprises (SMEs) and rank the firms based on their EO score. Nikfarjam et al. (2013) used FAHP for prioritizing environmental and internal factors of entrepreneurial university based on

Guerrero and Urbano (2010). Somsuk and Laosirihongthong (2013) identified the enabling factors influencing the success of university business incubators (UBIs) with respect to specific internal resources and prioritized them using FAHP. Calabrese et al. (2013) applied FAHP to assess the relative importance of intellectual capital (IC) components, with respect to their contribution to the company value creation, in order to obtain guidelines for IC management and investments. Nayebi et al. (2012) applied VIKOR technique for ranking the indices of organizational entrepreneurship development based on BSC factors which is one of the most critical tools for strategic appraisal in organization. Büyüközkan and Çifçi (2012) used FAHP and FTOPSIS in web service performance example of healthcare sector in Turkey.

Barriers to the Entrepreneurial University

If university management wishes to promote the entrepreneurial ideal, then identification of these institutional barriers is a necessity. While discussing the institution's support for entrepreneurial activity, informants revealed the existence of key barriers within their institutional context which they perceived as limiting progress. Philpott et al. (2011) identified barriers as lack of entrepreneurial role models within the university, absence of a unified entrepreneurial culture across the institution, and academic progression processes adversely affecting academic's entrepreneurial efforts. Other scholars have determined entrepreneurial university barriers as declines in per-student government funding (Todorovic et al. 2011), a more rigid bureaucratic control by the state, a lower base of research and inventive outputs coming out from the university, and lower demand and ability of private enterprises to commercialize university knowledge (Wong et al. 2007), inadequate links with business, clash with research objectives, lack of experience, inadequate cultural values, traditional ways of teaching, inappropriate reward system, clash with teaching objectives, lack of physical resources, etc (Guerrero 2007).

Research Methodology

Since a multiple criteria decision-making problem is subjective and qualitative in nature, it is very difficult for the decision-maker to express the strength of the preferences using exact numerical values (Somsuk and Laosirihongthong 2013). In real life, the weights of the criteria are usually expressed in linguistic terms. And also, to efficiently resolve the ambiguity frequently arising in available information and do more justice to the essential fuzziness in human judgment and preference, the fuzzy set theory has been used to establish an ill-defined multiple criteria decision-making problems (Ertugrul and Karakasoglu 2008). In practice, linguistic values can be represented by fuzzy numbers, and the triangular fuzzy number (TFN) is commonly used (Patil and Kant 2014).

Thus, in this paper, fuzzy AHP and fuzzy TOPSIS methods are proposed for entrepreneurial university selection, where the ratings of various alternatives under various subjective criteria and the weights of all criteria are represented by fuzzy

Table 1 Effective criteria of entrepreneurial university

Environmental factors		Internal factors	
Formal (EFs)	Informal (EIs)	Resources (IRs)	Capabilities (ICs)
•Entrepreneurial organizational and governance structure	•University community's attitudes towards entrepreneurship	•Human capital	•Status and prestige
•Support measures for entrepreneurship	•Entrepreneurial teaching methodologies	•Financial	•Networks and alliances
•Entrepreneurship education	•Role models and reward system	•Physical	•Localization
•Work discretion/autonomy	•Unconventionality	•Commercial	
•Industry collaboration	•Entrepreneurial culture		
•Sustainability considerations			

numbers. Determining the importance of criteria can help managers to make better decisions about the education system and university as a whole.

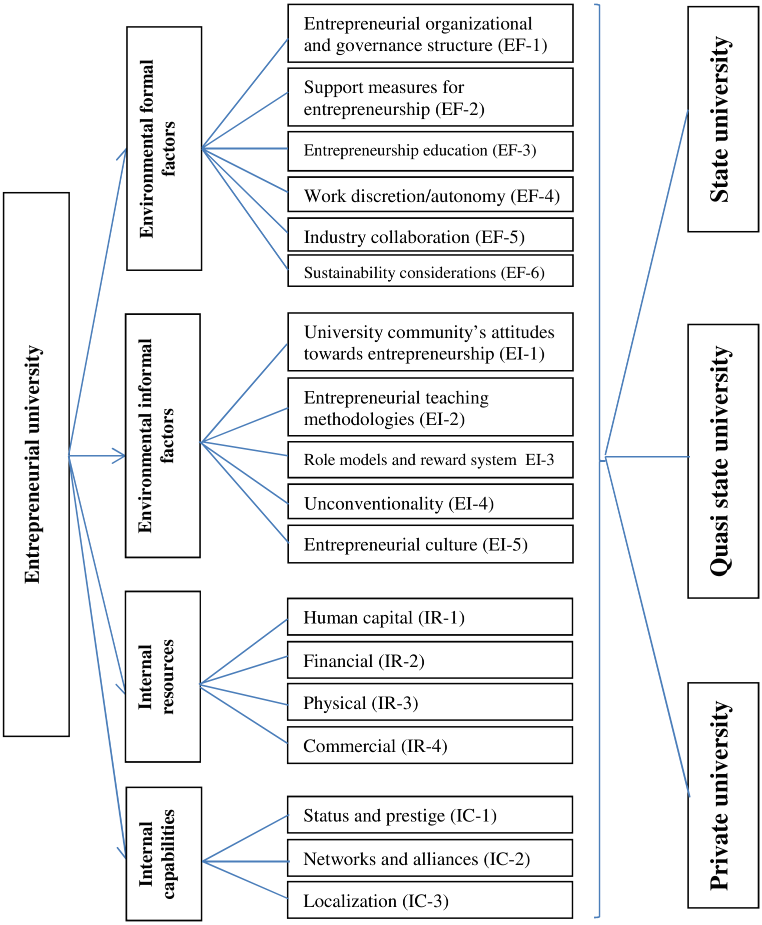

Fig. 1 Hierarchy of the entrepreneurial university

In this regard, based on the literature review, we summarize the entrepreneurial university criteria as Table 1.

The hierarchical structure of this research decision problem is shown in Fig. 1. After the construction of the hierarchy, the different priority weights of each criteria and attributes are calculated using the fuzzy AHP.

Fuzzy AHP

Here, we will briefly introduce how to carry out the fuzzy AHP in the following steps;

Step1. Construct pairwise comparison matrices among all the elements/criteria in the dimensions of the hierarchy system.

Step 2. Assign linguistic terms to the pairwise comparisons by asking which is the more important of each two dimensions, as matrix (1), $\widetilde{D}^{(k)}$.

$$\widetilde{D}^{(k)} = \begin{bmatrix} 1 & \widetilde{a}_{12}^{(k)} & \widetilde{a}_{1n}^{(k)} \\ \widetilde{a}_{21}^{(k)} & 1 & \widetilde{a}_{2n}^{(k)} \\ \vdots & \vdots & \vdots \\ \widetilde{a}_{n1}^{(k)} & \widetilde{a}_{n2}^{(k)} & 1 \end{bmatrix}; \mathrm{k} = 1, 2, \ldots, \mathrm{p} \quad (1)$$

Table 2 Linguistic terms and the corresponding triangular fuzzy numbers (Sen and Cinar 2010)

Linguistic term	Fuzzy number	Positive triangular fuzzy scale (*l*, *m*, *u*)
Extreme unimportance	$\widetilde{9}^{-1}$	(1/9, 1/9, 1/9)
Intermediate values between $\widetilde{7}^{-1}$ and $\widetilde{9}^{-1}$	$\widetilde{8}^{-1}$	(1/9, 1/8, 1/7)
Very unimportance	$\widetilde{7}^{-1}$	(1/8, 1/7, 1/6)
Intermediate values between $\widetilde{5}^{-1}$ and $\widetilde{7}^{-1}$	$\widetilde{6}^{-1}$	(1/7, 1/6, 1/5)
Essential unimportance	$\widetilde{5}^{-1}$	(1/6, 1/5, 1/4)
Intermediate values between $\widetilde{3}^{-1}$ and $\widetilde{5}^{-1}$	$\widetilde{4}^{-1}$	(1/5, 1/4, 1/3)
Moderate unimportance	$\widetilde{3}^{-1}$	(1/4, 1/3, 1/2)
Intermediate values between $\widetilde{1}$ and $\widetilde{3}^{-1}$	$\widetilde{2}^{-1}$	(1/3, 1/2, 1)
Equally importance	$\widetilde{1}$	(1, 1, 1)
Intermediate values between $\widetilde{1}$ and $\widetilde{3}$	$\widetilde{2}$	(1, 2, 3)
Moderate importance	$\widetilde{3}$	(2, 3, 4)
Intermediate values between $\widetilde{3}$ and $\widetilde{5}$	$\widetilde{4}$	(3, 4, 5)
Essential importance	$\widetilde{5}$	(4, 5, 6)
Intermediate values between $\widetilde{5}$ and $\widetilde{7}$	$\widetilde{6}$	(5, 6, 7)
Very vital importance	$\widetilde{7}$	(6, 7, 8)
Intermediate values between $\widetilde{7}$ and $\widetilde{9}$	$\widetilde{8}$	(7, 8, 9)
Extreme vital importance	$\widetilde{9}$	(9, 9, 9)

where $\widetilde{a}_{ij}{}^{(k)}$ is fuzzy comparison value of criterion i to criterion j that is assigned by kth expert and is $\widetilde{a}_{ij}^{(k)} = \left(l_{ij}^{(k)}, m_{ij}^{(k)}, u_{ij}^{(k)}\right)$. Corresponding TFNs used in this paper are shown in Table 2.

Step 3. Geometric mean of fuzzy comparison value of criterion i to criterion j, $\widetilde{r}_{ij}$ is obtained by

$$\widetilde{r}_{ij} = \left(\widetilde{a}_{ij}{}^{(1)} \otimes \widetilde{a}_{ij}{}^{(2)} \ldots \otimes \widetilde{a}_{ij}{}^{(p)}\right) 1/p \tag{2}$$

Step 4. Fuzzy weight of the ith criterion is

$$\widetilde{w}_i = \widetilde{w}_j = \widetilde{M}_i \otimes \left(\widetilde{M}_1 \otimes \widetilde{M}_2 \otimes \ldots \widetilde{M}_n\right)^{-1} \tag{3}$$

where $\widetilde{M}_i = \sum_{j=1}^{n} \widetilde{r}_{ij}$. Here, $\widetilde{w}_i$ or $\widetilde{w}_j$ is the fuzzy weight of the ith criterion, can be indicated by a TFN.

Fuzzy TOPSIS

Based on Sun (2010), fuzzy TOPSIS is carried out by the following steps;

Step 1. Construct the fuzzy performance/decision matrix and choose the appropriate linguistic variables for the alternatives with respect to criteria.

$$\widetilde{D} = \begin{bmatrix} \widetilde{x}_{11} & \widetilde{x}_{12} & \widetilde{x}_{1n} \\ \widetilde{x}_{21} & \widetilde{x}_{21} & \widetilde{x}_{2n} \\ \vdots & \vdots & \vdots \\ \widetilde{x}_{m1} & \widetilde{x}_{m2} & \widetilde{x}_{mn} \end{bmatrix}; \quad \mathrm{i} = 1, 2, \ldots, \mathrm{m}; \quad \mathrm{j} = 1, 2, \ldots, \mathrm{n}. \tag{4}$$

$$\widetilde{x}_{ij} = \frac{1}{p}\left(\widetilde{x}_{ij}{}^{(1)} \oplus \widetilde{x}_{ij}{}^{(2)} \oplus \ldots \oplus \widetilde{x}_{ij}{}^{(p)}\right) \tag{5}$$

where $\widetilde{x}_{ij}$ is the performance rating of alternative A_i with respect to criterion C_j evaluated by kth expert, and

$$\widetilde{x}_{ij}^{(k)} = \left(l_{ij}^{(k)}, m_{ij}^{(k)}, u_{ij}^{(k)}\right).$$

Step 2. Normalize the fuzzy decision matrix. The normalized fuzzy decision matrix denoted by $\widetilde{R}$ is shown as (6).

$$\widetilde{R} = \left[\widetilde{r}_{ij}\right]_{m \times n}, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{6}$$

Then, the normalization process can be performed by (7).

$$\widetilde{r}_{ij} = \left(\frac{l_{ij}}{u_j^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+}\right); u_j^+ = \max_i\left\{u_{ij} : i = 1, 2, \ldots, m\right\} \tag{7}$$

or we can set the best aspired level u_j^+ and j=1, 2,…, n is equal one; otherwise, the worst is zero. The normalized $\widetilde{r}_{ij}$ is still triangular fuzzy numbers. The weighted fuzzy normalized decision matrix is shown as matrix (8).

$$\widetilde{V} = \left[\widetilde{v}_{ij}\right]_{m \times n}, \quad i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n \tag{8}$$

where

$$\widetilde{v}_{ij} = \widetilde{v}_{ij} \otimes \widetilde{w}j. \tag{9}$$

Step3. Determine the fuzzy positive ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS).

According to the weighted normalized fuzzy decision matrix, we know that the elements $\widetilde{v}_{ij}$ are normalized positive TFN, and their ranges belong to the closed interval [0, 1]. Then, we can define the following FPIS A^+ (aspiration levels) and FNIS A^- (the worst levels) as (10), (11):

$$A^+ = \left(\widetilde{v}_1^*, \widetilde{v}_2^*, \ldots, \widetilde{v}_n^*\right) \tag{10}$$

$$A^- = \left(\widetilde{v}_1^-, \widetilde{v}_2^-, \ldots, \widetilde{v}_n^-\right) \tag{11}$$

where

$$\widetilde{v}_j^* = (1, 1, 1) \otimes \widetilde{w}_j = \left(lw_j, mw_j, uw_j\right) \quad \text{and} \quad \widetilde{v}_j^- = (0, 0, 0); j = 1, 2, \ldots, n. \tag{12}$$

Step 4. Calculate the distance of each alternative from FPIS and FNIS. The distances ($\widetilde{d}_i^+$ and $\widetilde{d}_i^-$) of each alternative from A^+ and A^- can be currently calculated by the area compensation method as follows:

$$d_i^+ = \sum_{j=1}^n d\left(\widetilde{v}_{ij}, \widetilde{v}_j^*\right), i = 1, 2, \ldots, m; \mathrm{j} = 1, 2, \ldots, n \tag{13}$$

$$d_i^- = \sum_{j=1}^n d\left(\widetilde{v}_{ij}, \widetilde{v}_j^-\right), i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{14}$$

$$d\left(\widetilde{A}, \widetilde{B}\right) = \sqrt{\frac{1}{3}\left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2\right]} \tag{15}$$

Table 3 Pairwise comparisons of attributes of environmental formal factors (EFs)

	EF-1	EF-2	EF-3	EF-4	EF-5	EF-6
EF-1	(1.000, 1.000, 1.000)	(0.891, 1.012, 1.157)	(1.012, 1.142, 01.316)	(0.772, 0.921, 1.065)	(0.781, 0.924, 1.115)	(0.982, 1.123, 1.412)
EF-2	(0.864, 0.988, 1.122)	(1.000, 1.000, 1.000)	(1.563, 1.688, 1.724)	(0.956, 1.124, 1.344)	(1.123, 1.325, 1.486)	(0.712, 0.892, 1.072)
EF-3	(0.760, 0.876, 0.988)	(0.580, 0.592, 0.640)	(1.000, 1.000, 1.000)	(2.145, 2.367, 2.647)	(0.623, 0.801, 0.989)	(0.812, 0.980, 1.154)
EF-4	(0.939, 1.086, 1.295)	(0.744, 0.890, 1.046)	(0.378, 0.422, 0.466)	(1.000, 1.000, 1.000)	(0.652, 0.836, 1.050)	(0.756, 0.901, 1.062)
EF-5	(0.897, 1.082, 1.280)	(0.673, 0.755, 0.890)	(1.011, 1.248, 1.605)	(0.952, 1.195, 1.534)	(1.000, 1.000, 1.000)	(1.025, 1.192, 1.352)
EF-6	(0.708, 0.890, 1.018)	(0.933, 1.121, 1.404)	(0.867, 1.020, 1.232)	(0.942, 1.110, 1.323)	(0.740, 0.839, 0.976)	(1.000, 1.000, 1.000)
Local fuzzy weight	(0.127, 0.164, 0.215)	(0.145, 0.188, 0.236)	(0.138, 0.177, 0.226)	(0.104, 0.138, 0.181)	(0.130, 0.173, 0.234)	(0.121, 0.160, 0.212)
Global fuzzy weight	(0.029, 0.045, 0.069)	(0.034, 0.051, 0.076)	(0.032, 0.049, 0.073)	(0.024, 0.038, 0.058)	(0.030, 0.047, 0.075)	(0.028, 0.044, 0.068)

Step 5. Obtain the closeness coefficients (relative gaps-degree) and improve alternatives for achieving aspiration levels in each criterion.

$$\mathrm{CC}_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{16}$$

Empirical Study

Selection of Decision Makers (Experts)

Some questionnaires were constructed to determine the degrees of preference by the help of the pairwise comparisons among criteria and attributes. The evaluation team,

Table 4 Pairwise comparisons of main criteria of entrepreneurial university

	EFs	EIs	IRs	ICs
EFs	(1.000, 1.000, 1.000)	(0.946, 1.058, 1.162)	(1.023, 1.165, 1.289)	(1.086, 1.178, 1.294)
EIs	(0.861, 0.945, 1.057)	(1.000, 1.000, 1.000)	(0.879, 1.034, 1.213)	(0.985, 1.085, 1.194)
IRs	(0.776, 0.858, 0.978)	(0.824, 0.967, 1.138)	(1.000, 1.000, 1.000)	(0.941, 1.062, 1.173)
ICs	(0.773, 0.849, 0.921)	(0.838, 0.922, 1.015)	(0.853, 0.942, 1.063)	(1.000, 1.000, 1.000)
Local fuzzy weight	(0.232, 0.274, 0.321)	(0.213, 0.253, 0.302)	(0.202, 0.242, 0.290)	(0.198, 0.231, 0.270)

Table 5 Pairwise comparisons of attributes of environmental informal factors (EIs)

	EI-1	EI-2	EI-3	EI-4	EI-5
EI-1	(1.000, 1.000, 1.000)	(0.724, 0.896, 1.052)	(0.985, 1.123, 1.261)	(0.842, 0.992, 1.148)	(0.876, 1.032, 1.186)
EI-2	(0.951, 1.116, 1.381)	(1.000, 1.000, 1.000)	(1.238, 1.425, 1.643)	(1.035, 1.143, 1.295)	(1.123,1.325, 1.486)
EI-3	(0.793, 0.890, 1.015)	(0.609, 0.702, 0.808)	(1.000, 1.000, 1.000)	(1.032, 1.194, 1.342)	(0.967, 1.084, 1.214)
EI-4	(0.871, 1.008, 1.188)	(0.772, 0.875, 0.966)	(0.745, 0.838, 0.969)	(1.000, 1.000, 1.000)	(0.958, 1.068, 1.174)
EI-5	(0.843, 0.969, 1.142)	(0.673, 0.755, 0.890)	(0.824, 0.923, 1.034)	(0.852, 0.936, 1.044)	(1.000, 1.000, 1.000)
Local fuzzy weight	(0.157, 0.199, 0.249)	(0.189, 0.238, 0.300)	(0.156, 0.193, 0.237)	(0.154, 0.189, 0.233)	(0.148, 0.181, 0.225)
Global fuzzy weight	(0.033, 0.050, 0.075)	(0.040, 0.060, 0.090)	(0.033,0.049,0.072)	(0.033, 0.048, 0.070)	(0.032, 0.046, 0.068)

composed of 12 experts, compared the criteria and attributes. This study applies snowball sampling by inviting seven entrepreneurship experts and five senior managers with extensive knowledge and experiences to evaluate the importance of the entrepreneurial university criteria and score 3 alternatives. Alternatives are three universities; one state university, one quasi-state university, and one private university. All experts are either managers with over 10 years of administrative experience in university

Table 6 Pairwise comparisons of attributes of internal resources (IRs)

	IR-1	IR-2	IR-3	IR-4
IR-1	(1.000, 1.000, 1.000)	(0.973, 1.095, 1.231)	(1.102, 1.214, 1.321)	(1.004, 1.142, 1.268)
IR-2	(0.812, 0.913, 1.028)	(1.000, 1.000, 1.000)	(0.895, 1.023, 1.138)	(0.956, 1.097, 1.178)
IR-3	(0.757, 0.824, 0.907)	(0.879, 0.978, 1.117)	(1.000, 1.000, 1.000)	(0.974, 1.086, 1.192)
IR-4	(0.789, 0.876, 0.996)	(0.849, 0.912, 1.046)	(0.839, 0.921, 1.027)	(1.000, 1.000, 1.000)
Local fuzzy weight	(0.234, 0.277, 0.325)	(0.210, 0.251, 0.293)	(0.207, 0.242, 0.284)	(0.199, 0.231, 0.274)
Global fuzzy weight	(0.047, 0.067, 0.094)	(0.042, 0.061, 0.085)	(0.042, 0.059, 0.082)	(0.040, 0.056, 0.080)

management or academic scholars with research concentration in entrepreneurship and over 10 years of teaching experience in related subjects.

On the basis of selected indicators, a survey was carried out to collect experts' perceptions on preferences among indicators. Experts' viewpoints on the various criteria and alternatives were received by personal interviews and filling out of the questionnaires on fuzzy AHP and fuzzy TOPSIS. The survey was conducted during the period from September to December 2013.

Weighing Entrepreneurial University Criteria

Fuzzy AHP is a comprehensive framework that is designed to cope with the rational and the irrational when we make multi-objective and multi-criterion without certainty for any number of alternatives. According to "Fuzzy AHP" section, fuzzy weights of environmental formal factors are computed for example. The aggregated pairwise comparison matrix is in Table 3.

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$, perform the fuzzy addition operation of m extent analysis values for a particular matrix

$$\sum_{j=1}^{6} \widetilde{M}_{\mathrm{EF-1}} = (5.438,\ \ 6.122,\ \ 7.065)$$

$$\sum_{j=1}^{6} \widetilde{M}_{\mathrm{EF-2}} = (6.218,\ \ 7.017,\ \ 7.748)$$

$$\sum_{j=1}^{6} \widetilde{M}_{\mathrm{EF-3}} = (5.920,\ \ 6.616,\ \ 7.418)$$

$$\sum_{j=1}^{6} \widetilde{M}_{\mathrm{EF-4}} = (4.469,\ \ 5.135,\ \ 5.920)$$

$$\sum_{j=1}^{6} \widetilde{M}_{\mathrm{EF-5}} = (5.558,\ \ 6.479,\ \ 7.662)$$

$$\sum_{j=1}^{6} \widetilde{M}_{\mathrm{EF-6}} = (5.189,\ \ 5.981,\ \ 6.953)$$

$$\sum_{\mathrm{i}=1}^{6} \widetilde{M}_{\mathrm{EF-}i} = (32.792,\ \ 37.344,\ \ 42.765)$$

$$\left[\sum_{\mathrm{i}=1}^{\mathrm{n}} \widetilde{M}_{\mathrm{EF-}i}\right]^{-1} = (0.023,\ \ 0.027,\ \ 0.030)$$

$$\mathrm{W}_{\mathrm{EF-1}} = (5.438, 6.122, 7.065) \otimes (0.023, 0.027, 0.030) = (0.127, 0.164, 0.215)$$

$$\mathrm{W}_{\mathrm{EF-2}} = (6.218, 7.07, 7.748) \otimes (0.023, 0.027, 0.030) = (0.145, 0.188, 0.236)$$

$$\mathrm{W}_{\mathrm{EF-3}} = (5.920, 6.616, 7.418) \otimes (0.023, 0.027, 0.030) = (0.138, 0.177, 0.226)$$

$$\mathrm{W}_{\mathrm{EF-4}} = (4.469, 5.135,\ \ 5.920) \otimes (0.023, 0.027, 0.030) = (0.104, 0.138, 0.181)$$

$$\mathrm{W}_{\mathrm{EF-5}} = (5.558, 6.479, 7.662) \otimes (0.023, 0.027, 0.030) = (0.130, 0.173, 0.234)$$

$$\mathrm{W}_{\mathrm{EF-6}} = (5.189, 5.981, 6.953) \otimes (0.023, 0.027, 0.030) = (0.121, 0.160, 0.212)$$

Applying the above procedure on main criteria of entrepreneurial university results in the fuzzy weight of those criteria in Table 4.

Table 7 Pairwise comparisons of attributes of internal capabilities (ICs)

	IC-1	IC-2	IC-3
IC-1	(1.000, 1.000, 1.000)	(0.932, 1.052, 1.197)	(0.846, 1.021, 1.184)
IC-2	(0.835, 0.951, 1.073)	(1.000, 1.000, 1.000)	(1.238, 1.425, 1.643)
IC-3	(0.845, 0.979, 1.182)	(0.609, 0.702, 0.808)	(1.000, 1.000, 1.000)
Local fuzzy weight	(0.275, 0.337, 0.407)	(0.305, 0.370, 0.447)	(0.243, 0.294, 0.360)
Global fuzzy weight	(0.055, 0.078, 0.110)	(0.060, 0.085, 0.121)	(0.048, 0.068, 0.097)

Now, by multiplying local fuzzy weight of each indicator in its own sub-criteria set to the fuzzy weight of corresponding main criteria, global fuzzy weight is obtained. For example, global fuzzy weight of EF-1 is computed as

$$(0.127,\ \ 0.164,\ \ 0.215)\otimes(0.232,\ \ 0.274,\ \ 0.321) = (0.029,\ \ 0.045,\ \ 0.069)$$

These weights are shown in the last row of Table 3. Applying this technique on attributes of environmental informal factors, internal resources, and internal capabilities result in global weight of those attributes. Decision matrices and final weights of those attributes are shown in Tables 5, 6, and 7.

At the second phase, we construct fuzzy TOPSIS decision matrix. Average of experts' preferences on three universities, state university (SU), quasi-state university (QSU), and private university (PU) is shown in Table 8.

Table 8 Fuzzy decision matrix

	EF-1	EF-2	EF-3	EF-4	EF-5	EF-6
SU	(5.024, 6.123, 6.842)	(3.362, 3.756, 4.215)	(4.356, 4.784, 5.132)	(7.364, 7.957, 8.325)	(4.325, 4.685, 4.993)	(5.324, 5.845, 6.245)
QSU	(2.142, 2.678, 3.351)	(0.458, 1.021, 1.742)	(3.674, 4.121, 4.745)	(3.547, 4.215, 4.859)	(2.954, 3.235, 3.645)	(4.142, 4.652, 4.967)
PU	(6.312, 6.758, 7.623)	(3.241, 3.845, 4.351)	(4.215, 4.685, 5.343)	(5.042, 5.623, 6.068)	(5.412, 5.872, 6.063)	(5.674, 6.214, 6.841)
	EI-1	EI-2	EI-3	EI-4	EI-5	IR-1
SU	(4.524, 4.985, 5.412)	(5.458, 5.876, 6.329)	(6.324, 6.741, 7.131)	(3.145, 3.486, 3.934)	(3.874, 4.254, 4.912)	(5.312, 5.671, 5.986)
QSU	(3.645, 4.052, 3.451)	(5.324, 5.645, 6.042)	(4.358, 4.712, 5.112)	(3.685, 4.125, 4.434)	(4.110, 4.483, 4.769)	(4.125, 4.635, 4.872)
PU	(5.681, 5.986, 6.524)	(6.014, 6.425, 6.861)	(5.268, 5.732, 6.124)	(5.325, 5.813, 6.241)	(5.412, 5.791, 6.098)	(5.241, 5.673, 6.038)
	IR-2	IR-3	IR-4	IC-1	IC-2	IC-3
SU	(5.954, 6.213, 6.421)	(6.478, 6.745, 6.978)	(4.385, 4.731, 5.064)	(7.632, 7.894, 8.234)	(5.368, 5.971, 6.341)	(3.458, 3.784, 4.121)
QSU	(3.756, 4.102, 4.435)	(4.358, 4.721, 5.063)	(3.985, 4.215, 4.652)	(3.421, 3.845, 4.152)	(4.197, 4.451, 4.821)	(4.541, 4.862, 5.213)
PU	(5.624, 5.967, 6.461)	(5.738, 6.231, 6.739)	(5.392, 5.846, 6.203)	(5.394, 5.714, 6.064)	(4.768, 5.130, 5.681)	(4.675, 4.989, 5.415)

Table 9 Normalized fuzzy decision matrix

	EF-1	EF-2	EF-3	EF-4	EF-5	EF-6
SU	(0.659, 0.803, 0.898)	(0.773, 0.863, 0.969)	(0.815, 0.895, 0.961)	(0.885, 0.956, 1.000)	(0.713, 0.773, 0.824)	(0.778, 0.854, 0.913)
QSU	(0.281, 0.351, 0.440)	(0.105, 0.235, 0.400)	(0.688, 0.771, 0.888)	(0.426, 0.506, 0.584)	(0.487, 0.534, 0.601)	(0.605, 0.680, 0.726)
PU	(0.828, 0.887, 1.000)	(0.745, 0.884, 1.000)	(0.789, 0.877, 1.000)	(0.606, 0.675, 0.729)	(0.893, 0.968, 1.000)	(0.829, 0.908, 1.000)
	EI-1	EI-2	EI-3	EI-4	EI-5	IR-1
SU	(0.693, 0.764, 0.830)	(0.796, 0.856, 0.922)	(0.887, 0.945, 1.000)	(0.504, 0.559, 0.630)	(0.635, 0.698, 0.806)	(0.880, 0.939, 0.991)
QSU	(0.559, 0.621, 0.529)	(0.776, 0.823, 0.881)	(0.611, 0.661, 0.717)	(0.590, 0.661, 0.710)	(0.674, 0.735, 0.782)	(0.683, 0.768, 0.807)
PU	(0.871, 0.918, 1.000)	(0.877, 0.936, 1.000)	(0.739, 0.804, 0.859)	(0.853, 0.931, 1.000)	(0.888, 0.950, 1.000)	(0.868, 0.940, 1.000)
	IR-2	IR-3	IR-4	IC-1	IC-2	IC-3
SU	(0.922, 0.962, 0.994)	(0.928, 0.967, 1.000)	(0.707, 0.763, 0.816)	(0.927, 0.959, 1.000)	(0.847, 0.942, 1.000)	(0.639, 0.699, 0.761)
QSU	(0.581, 0.635, 0.686)	(0.625, 0.677, 0.726)	(0.642, 0.680, 0.750)	(0.415, 0.467, 0.504)	(0.662, 0.702, 0.760)	(0.839, 0.898, 0.963)
PU	(0.870, 0.924, 1.000)	(0.822, 0.893, 0.966)	(0.869, 0.942, 1.000)	(0.655, 0.694, 0.736)	(0.752, 0.809, 0.896)	(0.863, 0.921, 1.000)

Table 10 Weighted normalized fuzzy decision matrix

	EF-1	EF-2	EF-3	EF-4	EF-5	EF-6
SU	(0.019, 0.036, 0.062)	(0.026, 0.044, 0.073)	(0.026, 0.043, 0.070)	(0.021, 0.036, 0.058)	(0.021, 0.037, 0.062)	(0.022, 0.037, 0.062)
QSU	(0.008, 0.016, 0.030)	(0.004, 0.012, 0.030)	(0.022, 0.037, 0.064)	(0.010, 0.019, 0.034)	(0.015, 0.025, 0.045)	(0.017, 0.030, 0.049)
PU	(0.024, 0.040, 0.069)	(0.025, 0.045, 0.076)	(0.025, 0.043, 0.073)	(0.015, 0.025, 0.042)	(0.027, 0.046, 0.075)	(0.023, 0.040, 0.068)
	EI-1	EI-2	EI-3	EI-4	EI-5	IR-1
SU	(0.023, 0.039, 0.062)	(0.032, 0.051, 0.083)	(0.029, 0.046, 0.072)	(0.017, 0.027, 0.044)	(0.020, 0.032, 0.055)	(0.042, 0.063, 0.093)
QSU	(0.019, 0.031, 0.040)	(0.031, 0.049, 0.080)	(0.020, 0.032, 0.051)	(0.019, 0.032, 0.050)	(0.021, 0.034, 0.053)	(0.032, 0.051, 0.076)
PU	(0.029, 0.046, 0.075)	(0.035, 0.056, 0.090)	(0.025, 0.039, 0.061)	(0.028, 0.045, 0.070)	(0.028, 0.044, 0.068)	(0.041, 0.063, 0.094)
	IR-2	IR-3	IR-4	IC-1	IC-2	IC-3
SU	(0.039, 0.058, 0.084)	(0.039, 0.057, 0.082)	(0.029, 0.043, 0.065)	(0.051, 0.075, 0.110)	(0.051, 0.080, 0.121)	(0.031, 0.047, 0.074)
QSU	(0.025, 0.039, 0.058)	(0.026, 0.040, 0.060)	(0.026, 0.038, 0.060)	(0.023, 0.036, 0.056)	(0.040, 0.060, 0.092)	(0.040, 0.061, 0.094)
PU	(0.037, 0.056, 0.085)	(0.034, 0.052, 0.080)	(0.035, 0.053, 0.080)	(0.036, 0.054, 0.081)	(0.045, 0.069, 0.108)	(0.042, 0.063, 0.097)

Table 11 Closeness coefficients to aspired level among different universities

	d_i^+	d_i^-	CC_i	Rank
SU	0.147	0.966	0.868	2
QSU	0.369	0.736	0.666	3
PU	0.118	1.004	0.895	1

PU ≻ SU ≻ QSU

Following the procedure of fuzzy TOPSIS in "Fuzzy TOPSIS" section, the normalized and weighted normalized matrices are in Tables 9 and 10.

By determining FPIS and FNIS from Table 10, distance of any alternative from FPIS and FNIS is obtained. Final ranking of alternative universities is shown in Table 11.

Findings show that the private university is more entrepreneurial than the other two universities. State university has better score in some measures as work discretion/autonomy, role models and reward system, human capital and physical resources, and status and networking because of expansive governmental supports. In general, all state universities in Iran are gaining financial aids from the government; therefore, most of them having more resources than quasi-state and private universities. Also, state ones have been utilizing experienced and distinguished professors to make them more prestigious. But, because of strategic vision and top management supports in private universities, those have centered their researches on real issues in industry. Therefore, collaboration of private universities with industry is typically more than the other ones. Quasi-state universities, because of their weakness in attracting and hiring experienced professors, less cooperation in research projects, and lesser financial aids from government, do not have good position from entrepreneurship's point of view. One of the most valuable efforts in private university under consideration is its attention to sustainability issues.

Conclusion

The aim of this paper is to explore the entrepreneurial university model. This paper develops a hierarchical structure based on the fuzzy analytic hierarchy process and ranks the alternative universities with the technique for order performance by similarity to ideal solution and fuzzy TOPSIS to help the academics and industrial practitioners for the entrepreneurial evaluation in a fuzzy environment where the vagueness and subjectivity are handled with linguistic values parameterized by triangular fuzzy numbers.

The proposed method enables decision analysts to better understand the complete evaluation process and provide a more accurate, effective, and systematic decision support tool. Findings show that, despite more resources and more supports from state universities, private alternative university in this study is more entrepreneurial than the other ones.

In this paper, we assumed that entrepreneurial university criteria are independent from each other. In future studies, researchers can focus on dependency among criteria with ANP and DEMATEL methods. Also, it is recommended to construct a fuzzy inference system with ANFIS to measure the entrepreneurial capacity of universities and students and professors.

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