APPLICATION OF A SWOT-FANP METHOD

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Abstract. Strengths, weaknesses, opportunities, and threats (SWOT) analysis is an effective strategic planning tool for the development of strategy formulation, but its main weakness is being incapable of quantitatively determining the weights and effects of alternative strategic criteria. Some studies' use of SWOT with analytic hierarchy process (AHP) would enable decision-makers to obtain-through pairwise comparisons-a relative priority of each criterion, so that the results from quantitative measures could overcome SWOT's central shortcoming. However, these studies neglect critical relationships or dependencies among SWOT factors. In this study, I propose a quantitative SWOT that rests on fuzzy analytic network process (FANP) methodology, includes possible dependencies among SWOT factors and permits the elimination of decision-makers' uncertain and vague preferences. To this end, I chose the Taiwan biotech pharmaceutical industry as an illustrative example. This study demonstrates and validates that such an enhanced methodology is viable and highly capable of providing enriched insights regarding strategic decision-making management in complex real-world situations.

Introduction

A report by the healthcare consultancy IMS Health estimates that China will overtake Germany and France as the world's third-largest prescription-drug market in 2011, trailing only the United States and Japan. The report said that pharmaceutical revenue in China is growing fast and that the market there may double by 2013 (D'Altorio 2010). Over the past

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twenty years, the Chinese pharmaceutical market has experienced an average annual growth of approximately 18–20%, significantly higher than US and European annual growth during that period (7–9%). The total pharmaceutical market is expected to become the world's largest pharmaceutical market by 2020 (Fu 2007). Pharmaceuticals, including bio-pharmaceuticals (fastest growing segment), are an important part of the high-tech industry in China (Wang *et al.* 2009).

Around the world, the biotech pharmaceutical industry has enormous opportunities to grow. Along with the technology development in the pharmaceutical field, nowadays the importance of biotech pharmaceutical products is greater than ever and increasing (Business Wire 2009). In China, the biotech pharmaceutical industry has been growing rapidly; indeed, it has been expanding at about 25% annually for the past few years and is poised for further expansion (Zhou 2007). According to research reports in *China Research and Intelligence* in 2008, the market size of the biotech pharmaceutical industry in China was about 70 billion yuan (about US$10 billion), a growth rate exceeding the whole market size of China's medicine market, including chemical medicine materials, chemical medicine doses, and traditional Chinese prepared medicines. Under the current global economic recession, the development of the biotech pharmaceutical industry of China has exhibited impressive momentum. There is no doubt that the role of China in the current and future global pharmaceutical market is and will be substantial; however, biotech pharmaceutical companies face uncertainties and ambiguities prevalent in the Chinese business environment, and therefore, how these companies choose an appropriate market-entry strategy has become an important issue. An accurate competitive strategy has positive effects on business performance (Kirca *et al.* 2005; Matsuno, Mentzer 2000; Olson *et al.* 2005; Vorhies, Morgan 2003). Continuing to show great interest in China, more and more companies from around the world are turning to a strategic approach as the way forward.

SWOT (standing for "Strengths, Weaknesses, Opportunities, and Threats") is a popular tool used for strategic-level decision-making. For instance, SWOT is the most widely used tool for major decision-making among executives working in Finland's 500 biggest companies (Stenfors, Tanner 2007). Its main application is to identify and analyze internal and external environments in support of strategic decision-making. When used properly, SWOT can provide a good basis for strategy formulation (Kajanus *et al.* 2004). However, SWOT analysis is not without limitations. SWOT analysis primary weakness is an overall dependence on qualitative analysis that merely ranks the importance of individual factors without quantitatively measuring them. Thus, SWOT analysis cannot comprehensively appraise strategic decision-making processes (Hill, Westbrook 1997); and thus, SWOT–analysis results often present a listing or an incomplete qualitative examination of internal and external factors (Kajanus *et al.* 2004).

Some researchers (Kurttila *et al.* 2000; Shrestha *et al.* 2004; Kajanus *et al.* 2004; Chang, Huang 2006) have proposed a systematic technique that combines SWOT with an analytic hierarchy process (AHP) and that is a mathematical method for analyzing complex decision-making problems with multiple criteria for determining relative importance. However, as planning processes are often complicated by numerous criteria and interdependencies, it may be that the use of AHP with SWOT is insufficient. For this reason, the current study performs SWOT analysis by using analytic network process (ANP), which not only combines both qualitative

and quantitative information, but also can deal with complex problems involving interactions among various factors. This hybrid method improves the usability of qualitative SWOT analysis for strategic-planning processes. However, decision makers are usually unable to identify with precision their preference owing to uncertain judgments that involve internal inconsistency and that are often expressed in linguistic terms. This makes fuzzy logic a more natural approach to this kind of problem. Recently, the use of fuzziness has been growing in research articles. However, there are far fewer studies on fuzzy ANP (FANP) than there are studies on fuzzy AHP (FAHP). Sipahi and Timor (2010) conducted a detailed literature review of the AHP and ANP methodologies, and the results show that between 2005 and 2009, SWOT with FANP was not present in the integrated methodologies involving such additional techniques as simulation, TOPSIS, GIS, and DEA used with AHP, FAHP, ANP, and FANP. In sum, this paper examines Taiwan biotech pharmaceutical companies trying to establish themselves internationally in China and treats the companies as an illustrative of the current study's proposed SWOT analysis featuring FANP. The findings not only should identify important factors of strength, weakness, opportunity, and threat, and help rank them according to their importance, but also should rank the alternative strategies according to their level of competitiveness for decision-makers.

The structure of this paper is as follows. The first section presents a comprehensive review of the literature covering SWOT analysis, the current status of China's biotechnology industry, the current status of Taiwan's biotechnology industry, and the ANP approach. The second section describes this study's fuzzy numbers and research process. The empirical analysis, findings, and validation of the model are discussed in Section 3. The final section concludes this paper and provides managerial implications.

1. Overview

1.1. SWOT analysis

A popular tool used for strategic-level decision-making, SWOT analyzes internal and external environments in order to attain a systematic approach to a decision situation (Kahraman *et al*. 2008). The aim of any SWOT analysis is to identify the key strengths and weaknesses of an organization and the opportunities and threats in the environment. The strengths and weaknesses are based on an "internal audit" of the organization. The opportunities and threats relate to "environmental factors" that decision-makers should take into account when planning strategic actions. Opportunities represent environmental factors that can be beneficially exploited, while threats need to be considered because of their potential to damage the organization (Gable *et al*. 2007).

Strategies are developed upon existing strengths, the elimination of weaknesses, the exploitation of opportunities, and the suppression of threats. SWOT identifies the strengths and weaknesses by conducting an internal appraisal of an enterprise and an external appraisal of the environment. The internal appraisal examines all aspects of the organization covering, for example, personnel, facilities, location, products, and services in order to identify the strengths and weaknesses of an organization. The external appraisal scans the political, economic, social, technological, and competitive environment with a view to identifying opportunities and threats (Dyson 2004).

The SWOT matrix produces four strategy alternatives based on matching external opportunities and threats with an organizationally-based internal strengths and weaknesses (Table 1). The strategy identified as SO involves making good use of opportunities by using the existing strengths of a given organization. WO is a strategy that, by accounting for weaknesses in an organization, functions to help the organization benefit from the opportunities of external environmental factors. Similarly, ST is a strategy that uses organizational strengths to remove or reduce threats. The fourth and last strategy is WT, in which the organization tries to reduce the effects of its threats by taking its weaknesses into account (Yűksel, Dağdeviren 2007).

Table 1. The SWOT matrix

	Strengths	Weaknesses
Opportunities	SO	WO
Threats	ST	WT

1.2. The current status of China's biotechnology industry

According to a current study from the American research institute IMS Health, the growth markets in the pharmaceutical industry lie no longer in the industrial countries but in emerging countries. Among all emerging countries, China has become the main focus of global pharmaceutical companies. The pharmaceutical market of China has shown double-digit revenue growth over the past two and a half decades (i.e. since about 1985), and drug revenue in China has been projected to grow by $40 billion through 2013 (Express Pharma 2011). The tremendous growth in the pharmaceutical market of China rests on several factors. First, with a population of 1.3 billion people, China has an expanding market-demand based on the country's large population. Second, there has been growing demand for medicine and healthcare in both urban and rural regions of China ever since the country instituted medical and healthcare reform with the goal that all Chinese have basic health care combined with committed governmental investment in pharmaceuticals. Additionally, Chinese can afford more pharmaceutical products owing to growth in the standard of living, disposable income, and average expenditure per person from disposable income. Industry-specific growth also comes from an emerging middle class and an aging population with out-of-pocket money available for medical treatment. Moreover, with consumer-behavior changes pertaining to such health-treatment patterns as self-prescribed medicine, over-counter medicine purchases, and on-line aspects of medicine, there is still space for expansion in the market. Last, illnesses sometimes associated with economic development have noticeably increased in China. Thus, in the last six years, the number of persons afflicted with heart problems and cancer has doubled while high blood pressure and diabetes are supposed to have increased by 200 percent, also resulting in a giant market. The above statistics suggest a positive outlook for the Chinese pharmaceutical market.

Among pharmaceuticals, biotech pharmaceuticals have been growing fastest. Biotech pharmaceuticals are a well-developed subset of the total biotechnology sector. Biotech pharmaceuticals are a priority in the medium-to-long-term plans for Chinese science-and-technology development (2006–2020), corresponding to the Eleventh 5-year Plan (2006–2010)

for the development of high-tech industries as well as to the Eleventh 5-year Plan for the development of the biotechnology industry. Chinese biotech pharmaceuticals certainly have great growth potential because they are a vital sector in the state's catch-up strategy and because the industry will be a recipient of vast funding (Wang *et al.* 2009). After 1978, biotechnology was first mentioned as a focal point of China's S&T development program. Following that, it became the top priority in the high-tech field. During the Ninth 5-year Plan (1996–2000), the biotechnology industry of China embraced a stage of steady growth in scale. Following that, the biotech pharmaceutical industry/market in China grew rapidly. Apart from expansion in industrial scale, the economic structure of the bio-pharmaceutical industry in China has been improved through the positive effects of recombination and shareholder reforms, which together accelerated and enlarged organizational-structure adjustments. However, many small and medium-sized enterprises (SMEs) in China have still confronted a lack of intellectual property rights, low R&D expenditure, and technological inferiority, determined by an industry wide high demand for technology, capital, and R&D resources. Nevertheless, during the Tenth 5-year Plan (2001–2005), especially after the admission of China into the World Trade Organization (WTO), an increasing number of foreign-funded companies surged into China to profit from China's high-end bio-pharmaceutical market. In response, domestic bio-pharmaceutical companies had to constantly reform and integrate so as to improve their degree of concentration and competitive ability, while giant foreign-funded companies were overwhelming most SMEs. Together with inner-industry or cross-industry mergers and reorganizations in Chinese biotech pharmaceuticals, the structure of biotechnology industry became much better balanced. In this period, the annual growth rate of the bio-pharmaceutical industry was over 20% (Wang *et al.* 2009).

Presently, there are more than 5,000 pharmaceutical companies around the world, and many of them are biotech pharmaceutical companies. Approximately 500 biotech pharmaceutical companies are in China and rope in annual sales proceeds of about 34 billion yuan; however, the share that these Chinese pharmaceuticals account for in the whole global pharmaceutical market is less than 10% (Wang *et al.* 2009). The domestic pharmaceutical market of China is highly fragmented and inefficient, with no single enterprise capable of controlling the market. The industry is small-scale, and also has a lower market concentration. Entering the WTO has created additional business opportunities for non-Chinese pharmaceutical companies in China and, in turn, has led to intense competition. Chinese Patent Law passed in December of 2008 has strengthened China's patent law and has increased the ceiling on monetary penalties for IP infringement (PricewaterhouseCoopers 2009b). On the whole, it would seem that the environment of the industry in China has changed for the better over the last several years. Nevertheless, intellectual property protection (IPP) has become a critical issue for foreign companies operating in China. Moreover, despite the rapid growth achieved in the past twenty years, the biotechnology industry of China operates under a large range of restrictions that severely threatens the industry as a whole and that involves such matters as limited funding, low investment, insufficient research personnel, inadequate domestic collaboration, poor competitive power, and innovation-lacking products (Wang *et al.* 2009).

1.3. The current status of Taiwan's biotechnology industry

Taiwan has been attempting to develop a successful biotech sector for about 25 years. Biotechnology is one of the six emerging industries specially selected by the Executive Yuan for intensive development. The efforts include tax deductions, R&D programs, low-interest loans, and discounted rental fees for land. In 2009, the government launched a new plan (named "Diamond Action Plan for Biotech Takeoff") for supporting development of the biotechnology industry. The plan contains four components: strengthening industrial value chains and pre-clinical development in the commercialization process, establishing a "biotechnology venture-capital" fund valued at US$1.9 billion, promoting an integrated incubation mechanism, and establishing the Taiwan Food and Drug Administration. As far as biotech companies in Taiwan are concerned, the limited total domestic market and small population size have hampered further domestic growth in Taiwan, leading Taiwanese companies to establish or expand their overseas market in search of business opportunities. Taiwanese companies have pushed outward by adopting the functions of contract research organizations (CROs) or contract manufacturing organizations (CMOs), processing technology transfers, participating in joint ventures, and establishing R&D centres.

The advantages for Taiwan in the biotech area are existing expertise in high technology, a highly educated workforce, a strong legal and regulatory support framework, abundant capital, government willingness to provide incentives, R&D capabilities, pre-clinical research, CROs, late-stage clinical trials, an abundance of high-quality medical facilities, and a national health-insurance system that produces a great deal of useful data. More important, Taiwan is geographically close to China, has important business connections with China, and shares with China basic linguistic, cultural, and ethnic characteristics, making Taiwan perhaps the ideal stepping stone to China for a variety of business opportunities.

Also many challenges and restraints exist for the biotechnology industry in Taiwan. Asian people generally have a much shorter-term investment mentality than Western people. People want a return on their money in two to three years, but investors in the biotech industry often can get no returns after two or three years (Amcham 2006). Upon realizing that investing in pharmaceuticals – especially in blockbuster small-molecule drugs – might take more than 20 years to pay off, investors shy away from placing their money in early-stage pharmaceutical products. Furthermore, Pin (2006) pointed out that Taiwan needs to re-position itself in the biotechnology market to seek its own "brand" at the international level in order to maintain or even increase its competitiveness. Today, even large pharmaceutical companies have difficulty developing viable new drugs. In Taiwan, the problem is a lack of experienced people in such fields as management, planning, drug development, and patent law. Moreover, most Taiwanese companies engage in small-scale R&D activities focusing on the development of generic versions of existing compounds. Worse yet, Taiwan has an insufficient R&D manpower supply, resulting in a lack of innovative competitiveness internationally. What Taiwan should do is strengthen its translational research, so the early-stage discoveries can be translated into commercial opportunities. Other obstacles hindering biotechnology development in Taiwan are tight budgets, insufficient experience in international channels, a lack of proper investment channels, a lack of strong brands, and a lack of effective solutions to counter investment risks.

1.4. Analytic network process (ANP)

The analytic hierarchy process (AHP) is a powerful tool for dealing with complex multi-cri-
teria decision-making problems, and can help to establish decision models that account for
both qualitative and quantitative components. The AHP helps analysts organize the critical
aspects of a problem into a hierarchy rather into a family tree (Bevilacqua *et al*. 2004). By
reducing complex decisions to a series of simple comparisons and rankings, and by then
synthesizing the results, the AHP not only helps the analysts to arrive at the best decision,
but also provides a clear rationale for the choices made (Chin *et al*. 1999). Since the AHP was
first proposed by Saaty (1980), it has been applied in a variety of fields. The AHP represents
a framework with unidirectional relationships among elements of the system, implying that
lower levels do not affect upper levels. A hierarchical model therefore is not appropriate for
a complex system involving interactions among various factors. The development of the
analytic network process (ANP) emerged to fill this gap.

The ANP – also introduced by Saaty (1996) – is the generic form of the AHP. The ANP
does not require hierarchical structures because it replaces any hierarchy in the AHP with
a network incorporating feedback and interdependent relationships among elements. Not
only does the importance of the criteria determine the importance of the alternatives as in
a hierarchy, but also the importance of the alternatives may affect the importance of the cri-
teria (Saaty 1996, 2006). The ANP provides a general framework for dealing with decisions
without generating assumptions about the independence between levels of a hierarchy (Saaty
2005). ANP can act as a valuable method for solving many multi-purpose, complicated
decision-making problems. Over the years, there have been many ANP methods applied by
various authors. Chung *et al*. (2005) developed a model for the selection of product mix with
an ANP application. Lee and Kim (2000) used ANP for interdependent information-system
project selection to find project priorities. In two studies by Meade and Sarkis (1998, 1999),
ANP served to identify appropriate logistic strategies and to improve production speed.
Momoh and Zhu (2003) used ANP to illustrate optimal production schedules. Partovi (2006)
presented a strategic solution to the facility-location problem, and the solution uses ANP
to incorporate both external and internal criteria into the decision-making process. Sarkis
(2002) presented a framework that, based on ANP, effectively treats tangible, intangible,
strategic, and operational factors in the strategic evaluation of suppliers. Tesfamariam and
Lindberg (2005) proposed an application of ANP in selecting the best among competing
system configurations. Ulutas (2005) specified an appropriate energy policy for Turkey. Wua
and Lee (2007) selected knowledge-management strategies using the ANP method. Yurdakul
(2003) constructed a model by using the ANP technique to evaluate long-term performances
of production systems.

The objective of this current study is to select the best entry strategy from alternatives
for Taiwan biotech pharmaceutical companies. The problem becomes complex owing to
numerous criteria that exhibit complex interactions with one another. It is not easy to analyse
most sets of criteria correctly. Therefore, it is necessary to identify a technique combining
both qualitative and quantitative information. An appropriate strategy is, it would seem, be
to use ANP as an analytic tool for strategy selection because of ANP's suitability in provid-
ing solutions in complex multi-criteria decision environments. Human beings cannot make

rigorous problem-solving decisions when the problems are so complex as to escape compre-hension. They often find solutions by rules of thumb or heuristic thinking based on binary logic. However, real life is full of uncertainty by nature. The results obtained by evaluating a situation or a system where certainty and absolutes govern perceptions of human issues prove inadequate in reflecting reality. Therefore, researchers apply fuzzy logic with fuzzy numbers to human judgments in order to eliminate avoidable vagueness, subjectivity, and imprecision. In short, perhaps the chief reason for using fuzzy logic is that it yields the most accurate results. Thus, Mikhailov and Singh (1999) conducted a comparative study on traditional crisp values and fuzzy intervals, and found that fuzzy measures perform better than crisp values. And thus, the current study uses FANPO methodology to solve problems concerning Taiwanese companies' selection of competitive strategies in China.

2. Fuzzy numbers and research processes

As mentioned above, human beings are often unable to make rigorous judgments because of the complexity of the matter at hand. Traditional multiple-attribute decision-making methods cannot effectively handle problems characterized by imprecision and vagueness. To resolve this issue, Zadeh (1965) introduced fuzzy set theory, which serves to illustrate the fuzzy phenomena occurring in human activities. The theory's function is to convert human behaviours and conceptual languages into fuzzy numbers using the uncertain elements of fuzzy set membership (Lee *et al.* 2011). Van Laarhoven and Pedrycz (1983) showed that these fuzzy numbers can be calculated and ranked.

The fuzzy sets are defined in terms of membership functions. Membership functions relative to X represent fuzzy subsets of X. The membership function representing a fuzzy set is usually denoted by μ_A. For an element x of X, the value $\mu_A(x)$ is called the membership degree of x in the fuzzy set. This function assigns to each element x of the universal set X a number $\mu_A(x)$ in the unit interval [0,1]. The membership degree $\mu_A(x)$ quantifies the grade of membership of the element x to the fuzzy set. An element x really belongs to A if $\mu_A(x) = 1$ and clearly does not if $\mu_A(x) = 0$.

A triangular fuzzy number can be denoted by three real numbers *(l, m, u)*. The parameters *l*, *m*, and *u* respectively stand for the smallest possible value, the most promising value, and the largest possible value. Its membership function can be defined as:

$$\left(d \right) = \begin{cases} 1, & \text{if } m_2 \geq m_1, \\ 0, & \text{if } l_1 \geq u_2, \\ \dfrac{l_1 - u_2}{\left(m_2 - u_2\right) - \left(m_1 - l_1\right)}, & \text{otherwise,} \end{cases}.$$

Detailed definitions and discussions of the arithmetic operations pertaining to triangu-lar fuzzy numbers can be found in Dubois and Prade (1978), Giachetti and Young (1997), Kaufmann and Gupta (1988), Wagenknecht *et al.* (2001), Kahraman *et al.* (2002), and Zadeh (1965).

The current study uses Chang's method. Let X = {x_1, x_2,..., x_n} be an object set, and U = {u_1, u_2,..., u_n} be a goal set. According to Chang's extent-analysis method (1992, 1996), each object is taken and an extent analysis for each goal (g_i) is performed. Therefore, m extent analysis values for each object can be obtained with the following signs:

$$M_{g_i}^1, M_{g_i}^2, ..., M_{g_i}^m, \quad i = 1, 2, ..., n \, , \tag{1}$$

where all the $M_{g_i}^j$ $(j = 1, 2, ..., n)$ are TFNs. The steps in Chang's extent analysis can be given as follows:

Step 1. The value of fuzzy synthetic extent with respect to the ith object is defined as:

$$S_j = \sum_{j=1}^m M_{g_i}^j \otimes \left(\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j \right)^{-1} . \tag{2}$$

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

$$\sum_{j=1}^m M_{g_i}^j = \left(\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j \right), \tag{3}$$

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

$$\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j = \left(\sum_{j=1}^m l_i, \sum_{j=1}^m m_i, \sum_{j=1}^m u_i \right). \tag{4}$$

Then compute the inverse of the vector in Eq. (4) such that:

$$\left[\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j \right]^{-1} = \left(\frac{1}{\sum_{i=1}^n u_i}, \frac{1}{\sum_{i=1}^n m_i}, \frac{1}{\sum_{i=1}^n l_i} \right). \tag{5}$$

Step 2. The degree of the possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 (l_1, m_1, u_1)$ is defined as: $V(M_2 \geq M_1) = \sup_{y \geq x} \left[\min \left(u_{M_1}(x), u_{M_2}(y) \right) \right]$ and can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = u_{M_2}(d) = \begin{cases} 1, & \text{if } m_2 \geq m_1, \\ 0, & \text{if } l_1 \geq u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{else,} \end{cases}$$

where *d* is the ordinate of the highest intersection point D between u_{M_1} and u_{M_2} .
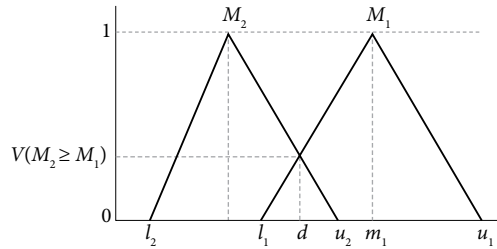
Fig. 1. Intersection of M_1 and M_2

To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$. This is given in Fig. 1.

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

$$V(M \geq M_1, M_2,\ldots, M_k) = V\left[(M \geq M_1) ve(M \geq M_2) \text{and}\ldots\text{and}(M \geq M_k)\right] = \min V(M \geq M_i),$$
$$i = 1,2,\ldots, k.$$

Assume that:

$$d'(A_i) = \min V(S_i \geq S_k).$$

For $k = 1, 2,\ldots, n; k \neq i$. Then the weight vector is given by:

$$W' = \left(d'(A_1), d'(A_2),\ldots, d'(A_n)\right)^T,$$

where $A_i (i = 1,2,\ldots,n)$ are n elements.

Step 4. Via normalization, the normalized weight vectors are:

$$W = \left(d(A_1), d(A_2),\ldots, d(A_n)\right)^T,$$

where W is a nonfuzzy number.

In this paper, Taiwanese biotech pharmaceutical companies are used as a case study. In researching the matter, a focus group discussion (FGD) was first held with eight experts to identify – following the aforementioned literature – preliminary comprehensive criteria belonging to strength, weakness, opportunity, and threat categories. Most of the experts had, individually, more than 15 years of experience in the identified pharmaceutical company, and occupied such positions as marketing and sales director, general manager, and manager. After completing this task, a total of 100 questionnaires featuring a five-item scale was sent to specialists in Taiwan; 56 valid samples were returned, the valid questionnaire rate being about 60%. The data from respondents was analysed to derive factor priority, and the ranking list with mean scores demonstrates the relative importance of each criterion within SWOT factors. Next, key criteria was identified that influenced strategy-selection decisions according to the same expert group. In this study, the top three criteria were chosen within each SWOT group to keep the number of pair-wise comparisons at a manageable level. The SWOT matrix and international-strategy alternatives on the basis of these criteria were sequentially developed (Table 2).

Table 2. The SWOT matrix

External factors	Internal factors	

	Strengths (S)
	– Advanced R&D
	  capability (S1)
	– Clinical trials (S2)
	– Marketing
	  capability (S3)
		Weaknesses (W)
		– Lack of strong brand (W1)
		– Lack of commercialization
		  capability (W2)
		– Lack of funding
		  support (W3)

Opportunities (O) – Population numbers (Size) (O1) – The reform of healthcare and medical-insurance systems (O2) – Emergence of healthcare concepts (O3)	**SO strategy** Niche-market strategy	**WO strategy** Generic-drug market strategy
Threats (T) – Government regulation of drug launches (T1) – Highly intensive competition (T2) – Inflation (T3)	**ST strategy** Marketing/sales services strategy	**WT strategy** Contract manufacturing market strategy

3. Proposed model implementation

Fig. 2 shows the relationships in a hierarchy SWOT model. This framework is divided into four levels. The first level is the goal. Factors within SWOT are listed in the second level. Each factor includes more criteria (located on the third level). The fourth level consists of four alternatives. The hierarchical model depicts a situation where there is no interaction among the criteria, while the loop diagram indicates a situation where there is interaction between factors. Appendix A presents the corresponding detailed definitions for each criterion and each alternative.
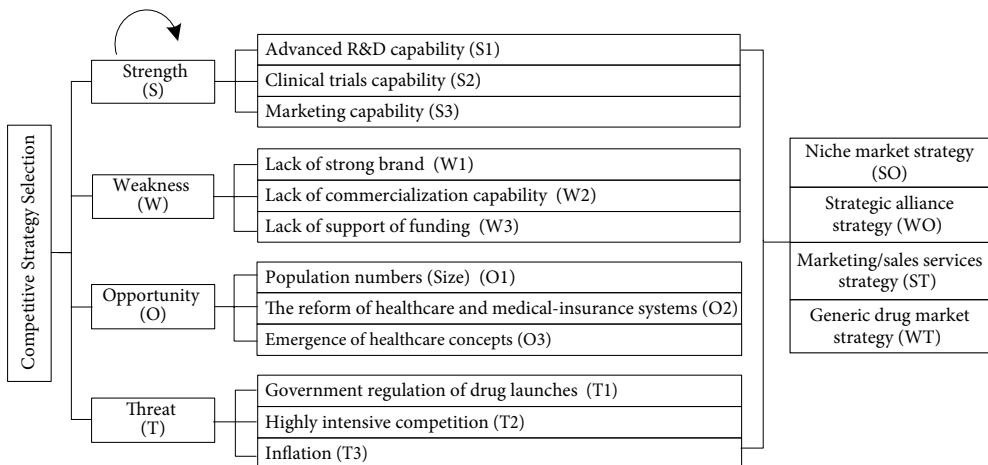

Fig. 2. A SWOT-ANP model for strategy selection

3.1. Determining the local weights of SWOT factors with respect to the goal

In this step, four assessment factors are compared to each other with respect to goal. The pair-wise comparisons rest on FGD and on the geometric mean rule; then pair-wise comparison matrices are formed with a fuzzy scale of 1–9. Using fuzzy values and Microsoft Excel software, I obtained the eigenvector as shown in Table 3.

Table 3. Pair-wise comparison matrix and weights of SWOT factors

Groups	S	W	O	T	$W_{SWOT(local)}$
S	1	1	1	1	0.25
W		1	1	1	0.25
O			1	1	0.25
T				1	0.25

3.2. Determining the inner dependence matrix among SWOT factors and calculating the global weights of SWOT factors

The factors were assumed to be dependent. Therefore, the impact of each group was analysed on all other factors by using pair-wise comparisons. According to the FGD serving to identify the inner loops among the factors, there are relations between the criteria in all factors, and four pair-wise comparison matrices for the factors based on inner dependencies were formed. An example of factor comparisons is the strength-vs.-weakness comparison using the question "How important is a strength when it is compared with a weakness?" The resulting relative-importance weights were calculated in terms of these inner-dependence matrixes (see Table 4 through Table 7, separately for each factor).

Table 4. The relative-importance weights for the "S" factor

S	S	W	O	T	Relative-importance weights
S	(1.000,1.000,1.000)	(1.000,2.000,3.000)	(2.000,3.000,4.000)	(2.000,3.000,4.000)	0.546
W	(0.333,0.500,1.00)	(1.000,1.000,1.000)	(0.333,0.500,1.000)	(1.000,1.000,1.000)	0.083
O	(0.250,0.333,0.500)	(1.000,2.000,3.000)	(1.000,1.000,1.000)	(1.000,2.000,3.000)	0.338
T	(0.250,0.333,0.500)	(0.500,1.000,1.000)	(0.333,0.500,1.000)	(1.000,1.000,1.000)	0.032

Table 5. The relative-importance weights for the "W" factor

W	S	W	T	Relative-importance weights
S	(1.000,1.000,1.000)	(1.000,1.000,1.000)	(1.000,2.000,3.000)	0.553
W	(0.500,1.000,1.000)	(1.000,1.000,1.000)	(1.000,1.000,1.000)	0.251
T	(0.333,0.500,1.000)	(0.500,1.000,1.000)	(1.000,1.000,1.000)	0.197

Table 6. The relative-importance weights for the "O" factor

O	S	O	Relative-importance weights
S	(1.000,1.000,1.000)	(0.333,0.500,1.000)	0.308
O	(1.000,2.000,3.000)	(1.000,1.000,1.000)	0.692

Table 7. The relative-importance weights for the "T" factor

T	S	W	T	Relative-importance weights
S	(1.000,1.000,1.000)	(1.000,1.000,1.000)	(1.000,1.000,1.000)	0.251
W	(0.500,1.000,1.000)	(1.000,1.000,1.000)	(0.333,0.500,1.000)	0.197
T	(0.500,1.000,1.000)	(1.000,2.000,3.000)	(1.000,1.000,1.000)	0.553

Then, by multiplying overall-dependence matrixes of the factors with the local weights of the factors, the global weights of the SWOT factors were obtained. Here it was found that the values for S, W, O, and T changed from 0.25 to 0.429, 0.25 to 0.174, 0.25 to 0.306, and 0.25 to 0.152:

$$W_{SWOT(global)} = \begin{bmatrix} 0.546 & 0.475 & 0.3358 & 0.338 \\ 0.083 & 0.384 & 0.000 & 0.228 \\ 0.338 & 0.000 & 0.642 & 0.000 \\ 0.032 & 0.141 & 0.000 & 0.443 \end{bmatrix} \begin{bmatrix} 0.25 \\ 0.25 \\ 0.25 \\ 0.25 \end{bmatrix} = \begin{bmatrix} 0.429 \\ 0.174 \\ 0.306 \\ 0.152 \end{bmatrix}.$$

3.3. Calculating the global weight of each criterion

Pair-wise comparison was used to calculate the local weight of each criterion within corresponding factors uses. The detailed pair-wise comparison matrices are shown in Table 8 through Table 11. Next, the global weights were multiplied for the SWOT factors obtained above with the corresponding local weights of the corresponding factors, and the last column in Table 12 yields the computed results for all criteria.

Table 8. Pair-wise comparison matrices and local weights for "S"-factor criteria

S	S1	S2	S3	$W_{S(local)}$
S1	(1.000,1.000,1.000)	(0.682,0.932,1.268)	(0.841,1.251,1.729)	0.354
S2	(0.789,1.072,1.466)	(1.000,1.000,1.000)	(0.578,0.895,1.091)	0.323
S3	(0.578,0.799,1.189)	(0.917,1.117,1.729)	(1.000,1.000,1.000)	0.323

Table 9. Pair-wise comparison matrices and local weights for "W"-factor criteria

W	W1	W2	W3	$W_{W(local)}$
W1	(1.000,1.000,1.000)	(1.290,1.611, 2.149)	(0.687,0.706,1.337)	0.179
W2	(2.258,2.876,3.300)	(1.000,1.000,1.000)	(1.367,1.586,2.325)	0.405
W3	(2.225,2.933,3.450)	(1.088,1.654,1.967)	(1.000,1.000,1.000)	0.416

Table 10. Pair-wise comparison matrices and local weights for "O"-factor criteria

O	O1	O2	O3	$W_{O(local)}$
O1	(1.000,1.000,1.000)	(0.771,1.130,1.476)	(0.278,0.410,0.565)	0.149
O2	(0.678,0.885,1.297)	(1.000,1.000,1.000)	(0.537,0.633,0.917)	0.181
O3	(1.769,2.441,3.591)	(1.091,1.579,1.861)	(1.000,1.000,1.000)	0.670

Table 11. Pair-wise comparison matrices and local weights for "T"-factor criteria

T	T1	T2	T3	$W_{T(local)}$
T1	(1.000,1.000,1.000)	(1.775,1.790,2.850)	(1.000,1.000,1.000)	0.623
T2	(0.351,0.410,0.563)	(1.000,1.000,1.000)	(1.238,1.300,2.267)	0.331
T3	(0.500,1.000,1.000)	(0.441,0.691,0.808)	(1.000,1.000,1.000)	0.046

Table 12. The computed results for all criteria

Group	$W_{SWOT(global)}$	Factor	$W_{SWOT(local)}$	$W_{Factor(global)}$
S	0.429	S1	0.354	0.152
		S2	0.323	0.139
		S3	0.323	0.139
W	0.174	W1	0.179	0.031
		W2	0.405	0.070
		W3	0.416	0.072
O	0.306	O1	0.149	0.046
		O2	0.181	0.055
		O3	0.670	0.205
T	0.152	T1	0.623	0.095
		T2	0.331	0.050
		T3	0.046	0.007

3.4. Determining the weights of alternative strategies with respect to each criterion

After obtaining the global weights for all criteria, I compared alternative strategies to one another with respect to each criterion. Table 13 presents the weights of the alternatives under each criterion.

Table 13. The weights of the alternatives under each criterion

Factor	Alternatives			
	SO	WO	ST	WT
S1	0.496	0.315	0.155	0.035
S2	0.370	0.340	0.182	0.108
S3	0.369	0.369	0.185	0.078
W1	0.229	0.276	0.254	0.242
W2	0.245	0.484	0.214	0.057
W3	0.406	0.357	0.208	0.028
O1	0.406	0.357	0.208	0.028
O2	0.406	0.357	0.208	0.028
O3	0.406	0.357	0.208	0.028
T1	0.305	0.407	0.176	0.112
T2	0.356	0.403	0.169	0.071
T3	0.384	0.430	0.110	0.077

3.5. Determining the overall priorities of the alternative strategies and obtaining the best "alternative strategies"

In this step, I calculated the final weights of "alternative strategies". By multiplying the global weight of each criterion with the values in Table 12, I obtained the priorities for the alternative strategy (Table 14). The SO strategy is the best strategy, with a 0.405 value. WO is the second best, with ST and WT occupying third and fourth place, respectively. Take $W_{\text{Alternative(SO,WO,ST,WT)}}$ under the strength factor as an example:

$$W_{\text{Alternative(SO,WO,ST,WT)}} = \begin{bmatrix} 0.496 & 0.370 & 0.369 \\ 0.315 & 0.340 & 0.369 \\ 0.155 & 0.182 & 0.185 \\ 0.035 & 0.108 & 0.078 \end{bmatrix} \begin{bmatrix} 0.152 \\ 0.139 \\ 0.139 \end{bmatrix} = \begin{bmatrix} 0.178 \\ 0.146 \\ 0.074 \\ 0.031 \end{bmatrix}.$$

Table 14. Results of alternative strategies

Factor	Alternatives			
	SO	WO	ST	WT
S	0.178	0.146	0.074	0.031
W	0.054	0.068	0.038	0.014
O	0.124	0.109	0.064	0.009
T	0.049	0.062	0.026	0.015
Sum	0.405	0.385	0.202	0.068

3.6. Validation of the model

The ANP is an approach that uses network structures to represent a multi-criteria decision-making problem and then determines the priority values for the factors from pairwise comparison matrices formed by the judgment of experts. The results will change depending

on expert judgments, or on the given conditions. Therefore, it is impossible for two sets of results to be the same. Although this limitation is embedded in the nature of decision-making problems, in the present study, it was striven to strengthen the validity of the proposed model in several ways.

Firstly, the judgments of the members of the FGD on pair-wise comparisons are combined using the geometric mean. In general, when combined judgments are used in a matrix often the answer is closer to the actual relative values than most of the individuals' answers are (Whitaker 2007). Therefore, this method was adopted, involving geometric means, to defend the validity of our proposed model. Secondly, the similar proposed model with AHP and FAHP was analysed by assuming that the SWOT factors are independent of one another. In addition, the ANP was applied to the same model. Regarding the alternative strategies, Table 15 presents the weights and priorities obtained from the four methodologies. Although same pairwise comparison matrices are implemented under different methodologies, it was found that the WO strategy is the best strategy according to the AHP and FAHP analyses, and that SO strategy is the best strategy according to the ANP and FANP analyses. Such a difference is understandable because ANP accounts for all kinds of dependencies among factors in complex decision-making problems, whereas AHP does not. Thus, the ANP method is better than the AHP method for reflecting real-world problems. The proposed model not only possesses the flexibility necessary for resolving real-world dilemmas, but is also a more suitable and effective decision-making tool in real-world applications. Lastly, the consistency ratio (CR) of the pairwise comparison is the other way to verify the validity of the mode. The CR is obtained by forming the ratio of the consistency index (CI) and the random index (RI). Saaty (1980) defined the CI and CR as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1}, \quad CR = \frac{CI}{RI},$$

were the λ_{max} is the maximum eigenvalue and n is the size of matrix.

For each size of matrix n, random matrices are generated and their mean CI value, or the RI, is computed. As suggested by Saaty (1994), the upper threshold CR values are 0.05 for a 3*3 matrix, 0.08 for a 4*4 matrix, and 0.10 for larger matrices (Lee *et al.* 2008). In this study, CR was used to measure the number of errors that occurred when providing the judgments. And the results show that the CR of the given pairwise comparisons is below 0.1. In other words, the errors are fairly small, and thus, it may be stated confidently that the final reliability of the pairwise comparison matrices is acceptable.

Table 15. Weights and ranking of the alternative strategies for the four methodologies

	AHP		ANP		FAHP		FANP	
SO	0.332	2	0.349	1	0.364	2	0.405	1
WO	0.334	1	0.329	2	0.375	1	0.385	2
ST	0.187	3	0.182	3	0.193	3	0.202	3
WT	0.147	4	0.140	4	0.069	4	0.068	4

3.7. Discussion

The purpose of this study is to select the most suitable competitive strategy for Taiwan biotech pharmaceutical companies. The findings strongly suggest that the niche-market strategy (the SO strategy) comes in at the top of the rankings.

Biotechnology is expected to play a vital role in the twenty-first century. Many biotech pharmaceutical companies' executives see China as *a* – if not *the* – key market. It has been widely recognized that a series of changes is currently underway in the global pharmaceutical industry. All major international pharmaceutical companies are currently experiencing a number of common challenges, both internally and externally. These challenges have forced the companies to take many critical steps: companies are streamlining their internal R&D operations in order to better exploit external resources; companies are pursuing a virtual R&D model by running their internal R&D in ways that are more akin to the methods of an R&D-focused biotech company and by placing greater emphasis on managing relationships with external partners; and companies are closing more domestic manufacturing facilities in order to outsource these general manufacturing tasks. All these actions function to make organizations more agile, adaptive, and flexible (Business Wire 2010).

Over the past 20 years, Taiwan has concentrated on developing its high-tech industries, and is now a world leader in the development and production of electronics, information technology (IT), computer products, and semiconductor products. Taiwan seeks to achieve the same level of success and global standing in biotechnology, the industry of the future. Taiwan has many strengths that give it an edge over its competitors in the rest of Asia. These strengths are due to a combination of existing conditions and to deliberate planning on the part of the government (BiotechEast 2011). The advantages for Taiwan are existing expertise in high technology, advanced R&D capability, a highly educated workforce, a strong legal and regulatory support framework, abundant capital thanks to the willingness of the government to provide incentives, lots of high-quality medical facilities, and a national health-insurance system that produces a great deal of useful data. In order to strengthen the international competitiveness of the biotech and pharmaceutical industries of Taiwan, the government of Taiwan has launched various R&D incentive programs to mitigate companies' product-and-technology development risks, thereby promoting companies' development of new products and technologies. What's more, as a result of China's and Taiwan's common language and cultural heritage, Taiwanese companies have a better understanding of local markets as well as the needs of local Chinese consumers, than do companies steeped in non-East Asian cultures. With the rising number of affluent Chinese, diseases such as diabetes, cancer, and cardiovascular diseases are on the rise, offering a huge need for drug development that specifically targets the Chinese market (PricewaterhouseCoopers 2009a). In 2010, Taiwan and China signed the bilateral trade accord known as the Economic Cooperation Framework Agreement (ECFA), and related study data that Taiwanese companies compiled about diseases and genotypes commonly found in Chinese communities should facilitate the development of new medicines for specific diseases or ailments to which people in China are vulnerable.

Conclusions

A SWOT analysis is a framework for identifying the strengths, weaknesses, opportunities, and threats that underlie the development of rigorous strategy formulation. Although an effective strategic planning tool, SWOT is weak chiefly because it cannot quantitatively determine the weight and the effects that the strategic factors bring to bear on the alternatives. Some studies used SWOT with AHP, enabling decision-makers to obtain – through pair-wise comparisons – the relative priority of each criterion, so that the results from quantitative measures can overcome the shortcomings of SWOT. However, these studies do not acknowledge that relationships or dependencies can arise regarding SWOT-analysis factors. In this study, a quantitative SWOT was proposed that rests on FANP methodology, that accounts for the possible dependencies among SWOT factors, and that eliminates decision-makers' uncertain and vague preferences. To execute the study, the Taiwan biotech pharmaceutical industry was chosen as illustrative of the examined topic. The model suggested herein consists of 1 goal, 4 assessment factors, 12 criteria, and 4 alternatives. The between-factor interactions help the data reflect the reality better than would otherwise be the case. This study has revealed that the most suitable competitive strategy for Taiwanese biotech pharmaceutical companies is the niche-market strategy.

Some distinguished contributions of this research are as follows. First, almost no previous study has explored the application of the SWOT-FANP methodology. In this study, an attempt was made to demonstrate and validate, with a case-study example, that it is possible to perform a rigorous quantitative SWOT-FANP analysis covering the possible dependencies among SWOT factors and eliminating decision-makers' uncertain and vague preferences. At its core, this study has demonstrated and validated that such an enhanced methodology is viable and highly capable of providing enriched insights for strategic decision-making management. Second, the present study has used several approaches to testing the validity of the proposed model. For instance, the geometric-mean approach was adopted so as to avoid individual experts' subjectivity. Moreover, the proposed model's results were compared with the results from the AHP, FAHP, and ANP models. The findings illustrate the best strategy for the case where there is a dependency between the SWOT factors. The obtained results indicate that dependencies among SWOT factors affect the strategy selection. This fact demonstrates that the proposed model is suitable and effective in complex world applications. In addition, the significance of experts' judgment errors was controlled by calculating a CR that ensures the acceptability of all pairwise comparisons. Finally, the proposed model was constructed to help biotech pharmaceutical companies select competitive strategies appropriate for the companies' own requirements. Although the decision criteria involved in any particular implementation may vary depending on the biotech pharmaceutical companies involved, this is one of the strengths of ANP, which can serve to construct various structures accounting for inner dependence and feedback effects. Decision-makers can rather easily use this model structure by modifying criteria or dependence within/between criteria designed for each application, depending on for the importance that decision-makers assigns to the application. The model proposed in the study can maintain its utility in the face of different industries.

In this study, not all possible criteria and interactions are considered. Future studies may incorporate important criteria belongings to the S, W, O, and T factors respectively, and also consider the effects of possible inter-dependence among the SWOT sub-criteria themselves to expand and refine the model. In addition, future research may apply the methodology of this current study to various areas of research as a way of verifying its effectiveness and usability. The findings acquired from such research could improve and further generalize the overall methodology.

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APPENDIX A

The definition of assessment factors and alternatives

Factor	Definition
Advanced R&D capability (S1)	A Taiwanese biotech pharmaceutical company's skilled and talented workers who can effectively study and create novel innovative products.
Clinical trials capability (S2)	A Taiwanese biotech pharmaceutical company's medical research and drug development procedures that serve to collect data on efficacy and safety (or more specifically, information about adverse drug reactions and adverse effects of other treatments) for health interventions (e.g. drugs, diagnostics, devices, therapy protocols).
Marketing capability (S3)	A Taiwanese biotech pharmaceutical company's ability to conduct promotional activities through advertising, public relations, and personal sales, with the goal of selling products, acquiring high-potential pharmaceutical-product customers, and addressing the unmet medical needs of customers.
Lack of strong brand (W1)	A Taiwanese biotech pharmaceutical company's deficiency in possessing an invaluable trademark reputation that embeds specific promises of value in customers' awareness.
Lack of commercialization capability (W2)	A Taiwanese biotech pharmaceutical company's deficiency in creating a marketable product.
Lack of funding support (W3)	A Taiwanese biotech pharmaceutical company's difficulty in obtaining sufficient long-term financing from diverse channels, including initial public offerings, venture capital, or cash flow from product sales.

Factor	Definition
Population numbers (size) (O1)	The total number of people inhabiting a specific area in China.
The reform of healthcare and medical-insurance systems (O2)	China's establishment of a medical and healthcare system with the goal that all Chinese have basic healthcare combined with (1) a commitment of pharmaceutical-bound governmental investment and (2) a demand for improved medicine and healthcare in both urban and rural regions.
Emergence of healthcare concepts (O3)	A greater understanding of well-being derived from increases in both the living standards and the personal disposable income of China's residents.
Government regulation of drug launches (T1)	China's highly complicated oversight of the introduction of pharmaceuticals.
Highly intensive competition (T2)	Biotech revenue growth in China alone is projected to exceed 25% so that both foreign and domestic biotech companies have competed in this market.
Inflation (T3)	A rise in the general level of prices of goods and services in an economy over a period of time. Price increases are pronounced in China.
Niche-market strategy (SO)	A Taiwanese biotech pharmaceutical company's entrance into a market by means of strategic alliances with external partners, with the goal of focusing on specific ailments to which people in Chinese communities are vulnerable (e.g. hepatitis B, liver cancer, oral cancer, diabetes mellitus, asthma, and nasopharyngeal cancer).
Generic-drug market strategy (WT)	A Taiwanese biotech pharmaceutical company's focus on expanding their role in the generic-drug market from upcoming patent expirations.
Marketing/ sales services strategy (ST)	A Taiwanese biotech pharmaceutical company's promotional activities such as marketing research, advertising, and consulting.
Contract manufacturing market strategy (WO)	A Taiwanese biotech pharmaceutical company's status as a contract manufacturing organization (CMO) that serves pharmaceutical companies by providing them with products and services based on a commitment to international standards, the end goal being to improve efficiency and productivity.

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