Critical success factors influencing the transformation of the agricultural biotechnology industry in Taiwan

Meng-Shiunn LEE

Department of Business Administration, Chang Jung Christian University, Tainan, Taiwan, R.O.C.

Abstract: The study uses the fuzzy Delphi and FANP (fuzzy analysis network process) methods to integrate the views of experts from enterprises and academia regarding the future direction of the agricultural biotechnology industry in Taiwan, in order to extract the critical success factors influencing its transformation. This study compares the differences in the "cross-domain" and "non-cross-domain" critical success factors, and expects that the research results could be a decision-making reference for both the industry and the government. The research results show that the cross-domain critical factor that influence the transformation of the agricultural biotechnology industry in Taiwan are sequentially: a stable source of raw materials, control of the trend of market demand, a new production equipment, the capability in supporting upstream and downstream industries, the integration of the human resources of the upstream, midstream, and downstream industries, and the capability in marketing and promotion. The non-cross-domain critical factors are sequentially: the capacity to establish the system of product technology, the capacity to control intellectual property rights, a perfect educational system, the capacity to carry out risk management of the new product development, the competence in cultivating the capacity of technical and R&D personnel, and laws and regulations.

Key words: agricultural biotechnology industry, transformation, critical success factors

Fifty years ago, after Watson and Crick found the double-helix structure of DNA, biotechnology began to develop rapidly and became one of the greatest contributions to mankind in the twentieth century, as well as the most promising star in terms of industrial development, having a great development potential. It is possible that biotechnology could lead the global economy to create huge business opportunities and profitability at a speed that is hard to imagine. Human beings will begin to encounter the bio-economy era. In the recent years, biotechnology has been applied in agriculture and other fields and has gradually been taken seriously worldwide (Sun 2006; Lee 2008). In the future, agricultural biotechnology will have a far-reaching impact on increasing the food production, protecting the natural environment and the Earth's resources, enhancing the well-being of farmers, and improving the quality of human life. In 2008, the Taiwanese Government announced biotechnology to be one of the six emerging industries and a subject of the future focus on the development of Taiwan's industries, which is directed towards the goal of "excellent agriculture." That means the Taiwanese Government will put a great effort into the full development of agricultural biotechnology.

With regard to the levels of agricultural science and technology development, Taiwan is one of the developed countries located in the temperate zone. Taiwan, which has the best environment for full development of the agricultural biotechnology industry, has niche advantages in the control of the germplasm and cultivation of agricultural products. In recent years, Taiwan has received the international recognition in the aspects of breeding and enhancing the production efficiency and quality of crops, and it is also one of the major exporters of agricultural technology. However, since joining the WTO (World Trade Organization), Taiwanese agriculture has increasingly encountered the competitive pressure caused by the import of agricultural products from other countries. Therefore, Taiwan's agricultural operations have confronted the issues of transformation and upgrading. In order to promote and ensure the sustainable development of the agricultural industry, the Taiwanese Government decided to facilitate the development of Taiwan's agricultural biotechnology as a means to enhance the agricultural competitiveness in Taiwan. If biotechnology can be effectively utilized to improve the application of agricultural products or to develop other types of applications, Taiwan's economic efficiency can be greatly promoted. Therefore, in 2006, the Taiwanese Government enacted "The Agricultural Biotechnology Industry Development Program," which positively promotes the multifaceted agricultural development, including the agricultural system, the look-ahead planning, policies, technology development, personnel training, funding strategies, market development, and the like, in order to create an environment and the supplementary systems that support the development of the agricultural biotechnology industry, to speed up the upgrading of the agricultural transformation, and to achieve the expected maximum effectiveness of the agricultural biotechnology industry in Taiwan.

Today, in the situation of the rapid development of technology and the knowledge economy, society as a whole is paying a special attention to the knowledge creation, as well as the positive effect of the distribution industry on technological development and industrial expansion. This kind of change in the structure of economic development not only affects the high-tech industry, but also the traditional agricultural industry, which has been protected by the Taiwanese policies. If both the cross-domain development and the non-cross-domain development of the agricultural biotechnology industry can be promoted in order to generate a new benefit, it is expected that Taiwan's agricultural biotechnology industry could have unprecedented opportunities (Lee 2008). The critical success factors influencing the transformation of the agricultural biotechnology industry in Taiwan are various and multifaceted. If researchers can use a hierarchical structure method to summarize and clarify the variety of influential factors, the conclusive results should be suitable for the simplification and use in decision making. In addition, the individuals' expression of points of views can inevitably sometimes be vague and uncertain. With some other complicated decision-making issues that involve the multi-attribute and complex hierarchical structures, the critical success factors influencing the transformation of the agricultural biotechnology industry in Taiwan could be interconnected and influence each other (Saaty 2006). Therefore, this study integrates the fuzzy theory into the Delphi and the fuzzy analytic network process (FANP) methods to deal with the fuzzy problems of this research issue in order to increase the accuracy of the research results.

In conclusion, this study uses the fuzzy Delphi method (FDM) and the fuzzy analytic network process (FANP) to integrate the experts' opinions from both the business and the scholarly sides about the future developmental direction of the agricultural biotechnology industry in Taiwan. Finally, the study extracts the critical success factors influencing the transformation of the agricultural biotechnology industry in Taiwan. In this study, the authors compare the differences between the cross-domain and the non-cross-domain critical success factors, in order to provide the industry and government with a decision-making reference.

LITERATURE

The developmental status of Taiwan's agricultural biotechnology industry

A report about the developmental status and planning of Taiwan's agricultural biotechnology industry in 2009 pointed out that the current development and the application of the agricultural biotechnology industry trends, on one hand, to be combined with the traditional fields of breeding, the disease control, fertilizers, pesticides, and so on, to enhance the productivity and quality of traditional agriculture, and on the other hand, to stimulate its new applications in the emerging biotechnology, it integrates the industries of agriculture and medicine, food and environment, and the like, in which the goal is to develop new application fields and to generate new opportunities for the agricultural industry. It seems that the development of agricultural biotechnology can be wide. This is also one of the reasons why many countries are making a great effort to develop their agricultural industry. According to the 2006 "White Paper on Biotechnology," the Taiwanese Government indicated that the application of agricultural biotechnology could be very wide and could extend to other relevant industries such as agriculture and environmental protection, or the Chinese herbal medicine and the biopharmaceutical industry – from the perspective of raw materials. Owing to the differences sourcing from the distinctive developmental directions and technological bases of different industries, the Taiwanese Government categorized agricultural biotechnology in Taiwan into eight classes in 2005, according to the "Strategic Planning Report of Agricultural Biotechnology in Taiwan." The classification was based on the characteristics and end-products of the industry. The eight classes are plant seeding biotechnology, aquaculture biotechnology, animal biotechnology, animal vaccine technology, food biotechnology, biological fertilizers, biological pesticides, and detection and diagnosis biotechnology. In addition, the Taiwanese Government has instructed the relevant governmental departments actively to follow up with the policies.

To comply with the rapid development trend of the agricultural biotechnology industry, over the years, the main issues for discussion at the meetings of the Strategic Review Board (SRB) have focused on the topic of "How to promote the research and development industrialization." Through the integrative cooperation program of production and research, the Taiwanese Government is practically implementing the industrialization plan in order to achieve the goal of advancing the industrial economics, the content of which has received a great deal of attention and includes sound laws and regulations, market development, product verification, construction of industrial parks, and other supporting measures to attract investments. In response to the trade liberalization and globalization, ensuring the sustainable development of agriculture, and bringing the advantages of Taiwan's agricultural science and technology and geographical condition into full play, in 2008, the Taiwanese Government proposed "Programs in Promoting Excellence in Intensive Agriculture." In the following years, the agricultural biotechnology industry was classified as one of the six emerging industries, and this excellent industry has been focusing on the technological development of agricultural biotechnology, orchids, ornamental fish, grouper, plant seeds, and others.

Literature on the critical success factors influencing the transformation and the transformative types of the agricultural biotechnology industry

The normal developmental stages of enterprises usually include development, maturity, and even decline. This type of phenomenon has pushed companies to pay a large amount of attention to the issue of transformation – if they want to operate sustainably. That is to say, to comply with the changes in the external environment, enterprises will focus on the requirements for transformation. Regarding the literature on change and transformation, this study refers to the developmental direction of the agricultural biotechnology industry and product attributes, and classifies the transformation of the agricultural biotechnology industry into two types. The first one is the non-cross-domain type of transformation, in which enterprises concentrate on the development of their existing product, but change the activities of production technology, marketing direction, market transformation, and the horizontal or vertical integration. For instance, the companies may fully or partially transform themselves from agricultural seeding biotechnology firms into gardening seeding biotechnology firms. That is, both of the skills belong to the same plant seeding biotechnology. That is the reason that the type one change is also named the non-cross-domain transformation. The second type is the cross-domain type of transformation. In the second type, enterprises give up their original products and operate in the existing or new business areas; at the same time, they invest in or operate products of the new business area to decrease the operational risk. For instance, enterprises may transform or diversify themselves from aquaculture biotechnology firms into food biotechnology firms, or into non-agricultural biotechnology firms, all of which are the cross-domain types of transformation (Bibeault 1982; Adrian 1996; Cheng 1996; Lee et al. 2007; Lee 2008; Lin et al. 2009).

With regard to the literature about the factors influencing the transformation, Bibeault (1982) indicated that the critical success factors influencing the enterprises' transformation mainly include: people, the companies' overall competitiveness, and the adequate bridge financing. Cheng (1996) suggested that the critical success factors should be: the control and analysis of the industrial trend, upstream and downstream industries' relevant professional knowledge, good interpersonal skills and relationships, successful capital management, and so on. The research results of Lee et al. (2007) showed that the critical success factors affecting the cross-domain transformation of small and medium semi-conductor manufacturers include: after-sales service, customer-oriented product design, competences in cultivating and training R&D staff and building up the communication network with customers, and the control of the market demands.

After an overview of the relevant literature, the authors expect to explore the critical success factors influencing the transformation of the agricultural biotechnology industry in Taiwan and to compare the differences between the cross-domain and the non-cross-domain critical success factors. Therefore, through the literature review, this study organizes the scholars' past research results into the aspects of the measurement dimension and the evaluative standards of the characteristics of agricultural biotechnology (Table 1) as the basis for the development of the initial hierarchical structure of the critical success factors influencing the transformation of the agricultural biotechnology industry in Taiwan in order to facilitate the subsequent empirical studies.

The development of the measurement dimensions

The so-called value chain is a series of value activities (VA) provided by enterprises to create valuable products or services for customers. Value activities not only create value for customers but also profits for the company. Each stage of the process of value activities contributes to the establishment of competitive advantage and competitiveness. Companies rely on these value-addition activities to achieve the goal of exchanging resources with external environments

Table 1. Integrative literature review of the dimensions influencing the transformation of agricultural biotechnology

Dimensions for measurement	Evaluative criteria	Source of literature
Business strategy	1. Economic growth trends	Cheng (1996)
	2. Market advantages	Arojarvi (2000)
	3. Advantages of economical scale	Löffler (2002)
	4. Planning and management	Croteau and Li (2003)
	5. Government attitude and regulations	Lofsten and Lindelof (2003)
	6. Level of connections between different industries	Lee et al. (2007)
	7. Competitive dynamics of relevant industries	Lee (2008)
Industrial environment	1. Economic growth trends	Bibeault (1982)
	2. Market advantages	Cheng (1996)
	3. Advantages of economic scale	Arojarvi (2000)
	4. Planning and management	Löffler (2002)
	5. Government attitude and regulations	Croteau and Li (2003)
	6. Level of connections between different industries	Lee et al. (2007)
	7. Competitive dynamics of relevant industries	Lee (2008)
Market orientation	1. Competence in controlling the marketing channels	Cheng (1996)
	2. Competence in designing customer-oriented products	Arojarvi (2000)
	3. Competence in producing customer-oriented products	Lee et al. (2007)
	4. Competence in controlling the stability of delivery	Lee (2008)
	5. Competence in establishing customer relationships	Lin et al. (2009)
	6. Competence in establishing mutual-trust relationships with customers	
	7. Competence in establishing a communication network with customers	
Marketing and services	1. After-sales service	Cheng (1996)
	2. Distribution channel	Arojarvi (2000)
	3. Wide range of products	Löffler (2002)
	4. Product life cycle	Lofsten and Lindelof (2003)
	5. Control the trend of market demand	Croteau and Li (2003)
	6. Fully functional service capabilities	Lee et al. (2007)
	7. Capability to develop new markets	Lee (2008)
	8. Capability to carry out integral marketing	Lin et al. (2009)
Technological development	1. Capability to undertake technological innovation	Cheng (1996)
	2. Capability to integrate production processes	Fearne and Hughes (1999)
	3. Production cost and quality	Arojarvi (2000)
	4. Material procurement and planning capacity	Croteau and Li (2003)
	5. Capability to reduce the manufacturing cycle	Lee et al. (2007)
	6. Capability to control the defect rate of the product	Lee (2008)
	7. Capability to control intellectual property rights	Lin et al. (2009)
Human resources	1. Personnel education and training	Bibeault (1982)
	2. Capability to manage human resources	Cheng (1996)
	3. Educational level of the leadership	Fearne and Hughes (1999)
	4. Characteristics of the top management team	Arojarvi (2001)
	5. Capability to control the quality of human resources	Croteau and Li (2003)
	6. Capability to cultivate the quality of R&D people	Lee et al. (2007)
	7. Capability to integrate human resources	Lee (2008) Lin et al. (2009)
Functional competences	1. Integration of the cross-functional competences	Bibeault (1982)
	2. Enterprise's financial strength	Cheng (1996)
	3. Assets and equipment	Fearne and Hughes (1999)
	4. Credit management of the enterprise	Arojarvi (2000)
	5. Sound financial structure	Croteau and Li (2003),
	6. Function and competences of the organizational structure	Lee et al. (2007)
		Lee (2008), Lin et al. (2009)

Note: The data are collected from the literature during the transactional process. Any industry is composed overall of a series of value activities. The acquisition and maintenance of competitive advantage depends on both an excellent value chain and a combination of the sustainable competitive advantages (SCA) and the industrial value chain system. Generally speaking, the value chain of an industry will vary due to the differences in industries. In the process of the industrial value chain, enterprises are able to distinguish clearly the allocation of the value-chain activities, to understand the scale of the added value created by VA, to ascertain the positioning of the industrial value chain held by the company, and to determine whether the company's position is suitable for intervening in other value-chain activities by way of vertical integration. The company's purpose is to obtain the additional value created by the vertical integration, or to add innovational activities to the existing industrial value chain, in order to change the current structure of the industrial value chain, which enhances the formation of the strategic competitive advantages. In other words, when the agricultural biotechnology industry is changing, it has to master the trend and competences to cope with the internal and external environment to maintain the competitiveness of the company.

Based on the foregoing literature review results, the study uses Porter's (1985) value-chain perspective to analyze the uniqueness and the superior competitive advantage of Taiwan's agricultural biotechnology industry as the fundamental measurement dimension of the critical success factors influencing its transformation, which also forms the research results that emerge in this study. The six dimensions are: rear service of procurement and output, production, marketing and after-sales service, procurement and infrastructure, human resources, and technological development.

Critical success factors and analysis method

Rockart (1979) suggested that if an enterprise can perform perfectly in some of the key areas, we can be assured that any of the competitiveness that enhances the success of the company can be viewed as the critical success factors of these areas. If companies want to grow continuously, they have to make efforts to manage this small number of key areas, otherwise they will not be able to achieve their operational target. Hofer and Schendel (1985) indicated that the critical success factors are actually a group of key variables, and managers' decision-making regarding these variables will affect the enterprises' competitive position within the industry. Lee (2008) mentioned that the critical success factors, which are also the prerequisites for business success, not only help enterprises to achieve their goal effectively, but also to obtain the SCA within the industry. The importance of the critical success factors has become the competitiveness or the competitive assets of an enterprise to survive and to compete successfully with others (Aaker 2009). Thompson et al. (2010) considered that the critical success factors represent the best competitiveness that each member of the industry would like to acquire and hold.

From the above literature on the definition of critical success factors, we can see that although many people have discussed the importance of critical success factors, how to identify the critical success factors has become a major concern of the researchers. For example, the critical success factors influencing the transformation of the agricultural biotechnology industry in Taiwan are multifaceted. Through the hierarchical structural analytical method (in this case, we use the FANP), these critical success factors can be summarized, simplified, and referred to during the decision-making process. Individuals may be over-subjective when expressing their opinions. Thus, through a flexible evaluation and a measurement tool, the over-subjective issues, such as the fuzziness of the consensus of the experts' viewpoints, can be solved. For this reason, this research adopts the Delphi method, which is generated from the fuzzy theory, and the FANP, to analyze the data and to deal with the possible fuzziness problem caused during the process of the experts' decision-making and setting up the criteria to judge the critical success factors influencing the transformation of the agricultural biotechnology industry in Taiwan. The goal is to ensure that the selected critical success factors are accurate and definite.

RESEARCH METHOD

Establishment of levels (the hierarchical structure)

In accordance with the literature (Table 1) and the value-chain perspective of Porter (1985), this study forms the dimensions and the initial hierarchical structure measuring the factors influencing the transformation of the agricultural biotechnology industry in Taiwan as the basis for designing the questionnaire and the selection standards of the dimensions, which enhance the process of the empirical research of this study. The structure demonstrates that the ultimate goal of this study is to extract the critical success factors influencing the transformation of the agricultural biotechnology industry in Taiwan. Then, the structure is further divided into a major goal, a secondary goal, and thirty items for assessment. To attain the level consistency (in the hierarchical structure) and a reasonable and effective pairwise comparison, the study follows Saaty's (1980) suggestion that the number of items in each level should not be over seven (Figure 1).

Questionnaire design and study

The first stage of the questionnaire design is the formation of the fuzzy Delphi expert questionnaire, which is based on the initial hierarchical structure established previously. The fuzzy Delphi expert questionnaire in the first stage is mainly to evaluate the importance and the appropriateness level of the measurement dimensions and criteria for the evaluation of the critical success factors. The content of the questionnaire consists of the respondents' basic information, the instructions for filling in the questionnaire, and the main themes of the survey; there are three main parts in total. The evaluative grades range from 1 to 10 – higher scores represent higher importance levels. In addition to indicating the acceptable range and the expected level of importance, the respondents can also write down their own opinions in an open space following each question, which requires the respondents to offer their previous experiences and judgment regarding the best strategies and criteria for assessment by filling in the integral grading numbers. Moreover, using the research results of the first stage, the study selects the factors with a high importance level, as indicated by the consensus of the experts, and establishes a complete strategic hierarchical structure in order to design the second stage's questionnaire, which is based on the FANP. The content of the questionnaire consists of the hierarchical structure, the respondents' basic information, the content of the questionnaire, and instructions for answering the questions. The content of the questionnaire can be

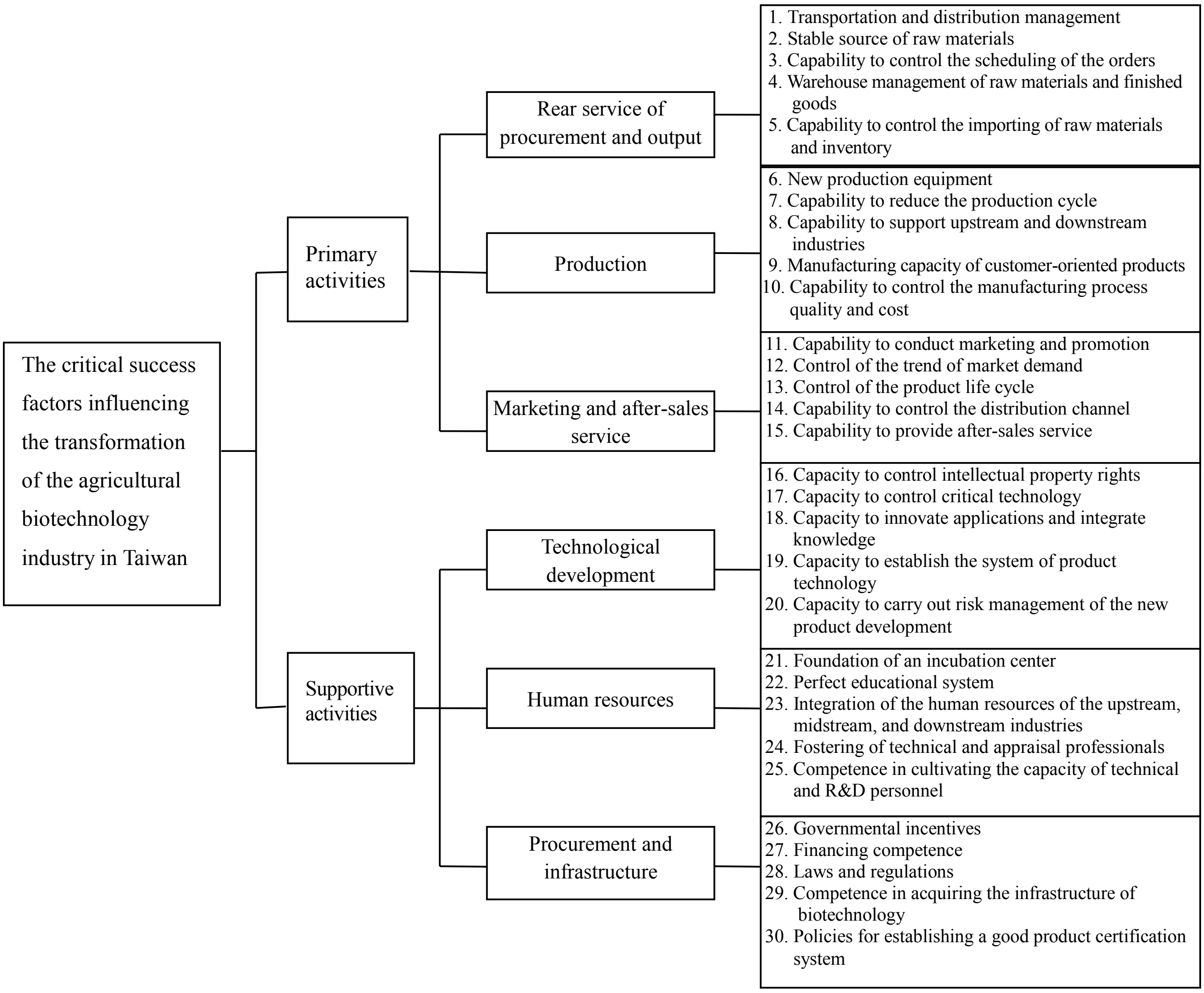

Figure 1. Initial hierarchical structure

Data source: this study

divided into two parts: sorting of the importance levels of the assessment criteria; and the pairwise comparison of the results. The assessment can be made using a scoring system of 1 to 9 and combined with a pairwise comparison method.

The analysis of this study is conducted in two stages. Regarding the number of samples, to obtain objective measurement dimensions and criteria for evaluation, this study uses the talent pool of the Agricultural Biotechnology Industry Information Center to select the major sample objects of this study. The first phase utilized the judgmental sampling method and distributed 35 copies of the fuzzy Delphi expert questionnaires; 32 valid questionnaires were collected. As indicated before, based on the characteristics and end-products of the industry, the authors classified the industries into eight classes; for each class of the industry, 2 experts were drawn from the academia and two from the industry. In phase two, the study also utilized 37 copies of the fuzzy Delphi expert questionnaire; 32 valid questionnaires were collected in total. Also, in the second stage, for each class of sub-industry, 2 experts were drawn from the academia and 2 from the industry.

Data analysis

Fuzzy Delphi method (FDM)

The fuzzy Delphi method integrates the concept of the fuzzy theory into the Delphi method, and uses the bi-triangular fuzzy arithmetic to organize the opinions of experts. Through the gray zone test method, the fuzzy Delphi method tests whether the experts' opinions achieve a convergent level. An acceptable level of convergence indicates that the experts' opinions have reached consensus well (Hwang and Lin 1987; Hsu 1998; Cheng 2001; Lee 2008). That is to say, the fuzzy Delphi method is a rigorous research method, which is manipulated in stages as described below. (1) According to the initial hierarchical structure (figure 1), the authors design the fuzzy Delphi expert questionnaire; (2) based on "the most conservative cognitive value" and "the most optimistic cognitive value" given by the experts (*i*), the study establishes the bi-triangular fuzzy arithmetic; (3) the study tests the level of consensus of the experts; and (4) finally, based on the highest possible value given by the experts, the authors calculate the geometric means, which are the basis that they use to calculate the arithmetic means (the threshold value of this study). These threshold values are to help the authors to select the appropriate number of the evaluative criteria that is concluded by the experts. In the end, according to the results, the study is again based on the ultimate goal, second goal, and evaluative items, sequentially developing the strategic hierarchical structure.

Fuzzy analysis network process (FANP)

The FANP integrates the fuzzy theory into the analysis network process method (Saaty 1996) to conduct a variety of assessments of the weight and importance level of each factor, in order to attain more objective and reasonable critical success factors (Buckley 1985; Robbins 1994; Hsu 1998; Büyüközkan et al. 2004; Lin 2006). Its analytical process is as follows: (1) to design a questionnaire based on the strategic hierarchical structure; (2) to establish a pairwise comparison matrix; (3) to establish the triangular fuzzy arithmetic; (4) to establish a fuzzy positive reciprocal matrix; (5) to test the consistency of the fuzzy matrix; (6) to calculate the fuzzy weights of the fuzzy matrix in different stages; (7) to process de-fuzziness and standardization; (8)to establish and analyze a super-matrix, and to calculate the overall weights of the hierarchy.

RESEARCH RESULT

The phase-one fuzzy Delphi questionnaire survey – selecting the high-importance assessment criteria based on the expert consensus

First, according to the initial hierarchical structure (Figure 1), this study designs an FDM expert questionnaire to search for the critical success factors influencing the agricultural biotechnology industry in both the cross-domain and the non-cross-domain type of transformation. After the interviews, the authors use the Excel to run the data and thus obtain the triangular fuzzy arithmetic of the most conservative cognitive value ($L^i = (L^i_L, L^i_M, L^i_U)$) of each item for evaluation (*i*) and the triangular fuzzy arithmetic of the most optimistic cognitive value $U^i = (U^i_L, U^i_M, U^i_U)$, of which L^i_L, L^i_M and L^i_U are the minimum number, geometric mean, and maximum value of the most conservative cognitive value. U^i_L, U^i_M and U^i_U are the minimum number, geometric mean, and maximum value of the most optimistic cognitive value. The gray zone test method results demonstrate that each evaluation item reached a convergence level in the study's first interviews with the experts. Thus, there was no need to conduct a second repetitive interview. Finally, the value of the importance level T^i is produced in accordance with the experts' consensus (of each item *i*), as well as the threshold values of the cross-domain

Table 2. Analytical result of the fuzzy Delphi questionnaire in the cross-domain aspect

Dimension	Assessment criteria	The most conservative cognitive value (L_L^i, L_M^i, L_U^i)			The most optimistic cognitive value (U_L^i, U_M^i, U_U^i)			The geometric mean of the highest possible values	T^i
Rear service of procurement and output	1. Transportation and distribution management	4	6.0	7	7	8.2	10	7.7	7.20
	2. Stable source of raw materials	5	6.2	8	7	8.2	10	7.5	7.55
	3. Capability to control the scheduling of the orders	4	6.0	7	7	8.2	10	7.1	7.10
	4. Warehouse management of raw materials and finished goods	5	6.4	8	8	8.8	10	8.1	7.60
	5. Capability to control the importing of raw materials and inventory	4	5.4	7	7	8.7	10	6.8	7.05
Production	6. New production equipment	5	6.5	8	8	8.6	10	7.4	7.55
	7. Capability to reduce the production cycle	4	6.1	8	8	8.8	10	7.4	7.45
	8. Capability to support upstream and downstream industries	6	7.1	8	8	9.0	10	7.8	8.05
	9. Manufacturing capacity of customer-oriented products	4	6.4	8	8	8.9	10	7.6	7.65
	10. Capability to control the manufacturing process quality and cost	4	6.3	8	8	8.8	10	7.7	7.55
Marketing and after-sales service	11. Capability to conduct marketing and promotion	5	6.5	8	8	8.7	9	7.8	7.60
	12. Control of the trend of market demand	5	6.6	8	8	9.1	10	7.8	7.85
	13. Control of the product life cycle	5	5.5	8	8	8.9	10	7.0	7.20
	14. Capability to control the distribution channel	5	6.6	8	7	8.8	10	7.8	7.56
	15. Capability to provide after-sales service	5	6.1	7	8	9.1	10	7.3	7.60
Technological development	16. Capacity to control intellectual property rights	6	7.0	8	8	9.4	10	8.9	8.20
	17. Capacity to control critical technology	5	6.2	7	8	8.9	10	7.5	7.55
	18. Capacity to innovate applications and integrate knowledge	4	6.0	8	8	9.0	10	7.2	7.50
	19. Capacity to establish the system of product technology	4	6.7	9	7	8.8	10	7.8	7.88
	20. Capacity to carry outrisk management of the new product development	4	6.1	8	7	8.7	10	7.6	7.47
Human resources	21. Foundation of an incubation center	5	5.9	8	7	8.1	10	7.4	7.12
	22. Perfect educational system	6	7.1	8	9	9.3	10	8.1	8.20
	23. Integration of the human resources of the up-stream, midstream, and downstream industries	6	6.6	7	8	8.9	10	8.2	7.75
	24. Fostering of technical and appraisal professionals	5	5.9	7	7	8.2	10	7.3	7.05
	25. Competence in cultivating the capacity of technical and R&D personnel	5	6.8	8	7	8.6	10	7.4	7.57
Procurement and infrastructure	26. Governmental incentives	5	5.9	7	8	8.6	9	8.0	7.25
	27. Financing competence	6	7.4	9	9	9.1	10	8.0	8.25
	28. Laws and regulations	6	6.6	7	8	9.1	10	7.2	7.85
	29. Competence in acquiring the infrastructure of biotechnology	5	6.6	8	7	8.7	10	7.8	7.55
	30. Policies for establishing a good product certification system	5	6.5	8	7	8.5	10	7.4	7.50
	The threshold value			7.35					

Source of data: this study

Notes: The gray area represents the removed assessment criteria

Table 3. Analytical result of the fuzzy Delphi questionnaire in the non-cross-domain aspect

Dimension	Assessment criteria	The most conservative cognitive value $\left(L_L^i, L_M^i, L_U^i\right)$			The most optimistic cognitive value $\left(U_L^i, U_M^i, U_U^i\right)$			The geometric mean of the highest possible values	T^i
Rear service of procurement and output	1. Transportation and distribution management	5	5.8	8	7	8.1	10	7.1	7.38
	2. Stable source of raw materials	4	5.5	7	8	8.6	10	7.0	7.05
	3. Capability to control the scheduling of the orders	6	6.7	8	7	9.0	10	7.9	7.61
	4. Warehouse management of raw materials and finished goods	4	6.1	8	6	8.0	10	7.0	7.03
	5. Capability to control the importing of raw materials and inventory	4	5.5	8	7	8.4	10	6.6	7.36
Production	6. New production equipment	6	7.1	8	8	9.0	10	8.0	8.05
	7. Capability to reduce the production cycle	4	5.8	7	7	8.2	9	7.2	7.00
	8. Capability to support upstream and downstream industries	6	6.5	7	7	8.7	10	7.1	7.60
	9. Manufacturing capacity of customer-oriented products	4	5.7	7	8	8.8	10	7.3	7.25
	10. Capability to control the manufacturing process quality and cost	5	5.4	6	7	8.2	9	7.0	6.80
Marketing and after-sales service	11. Capability to conduct marketing and promotion	6	6.5	7	7	8.8	10	8.1	7.65
	12. Control of the trend of market demand	5	6.6	8	7	8.5	10	7.7	7.52
	13 Control of the product life cycle	5	6.6	7	7	8.8	10	7.9	7.70
	14. Capability to control the distribution channel	6	7.2	8	8	9.1	10	8.3	8.15
	15. Capability to provide after-sales service	6	6.9	8	8	9.1	10	8.1	8.00
Technological development	16. Capacity to control intellectual property rights	6	6.7	8	8	8.9	10	7.8	7.80
	17. Capacity to control critical technology	5	5.8	7	7	8.1	9	6.5	6.95
	18. Capacity to innovate applications and integrate knowledge	5	5.8	7	7	8.3	10	6.3	7.05
	19. Capacity to establish the system of product technology	4	6.1	8	8	9.2	10	7.8	7.65
	20. Capacity to carry outrisk management of the new product development	4	5.9	7	8	9.0	10	7.7	7.45
Human resources	21. Foundation of an incubation center	5	5.7	7	7	8.2	9	6.7	6.95
	22. Perfect educational system	6	6.7	8	8	9.2	10	7.8	7.95
	23. Integration of the human resources of the up stream, midstream, and downstream industries	5	5.4	6	7	7.6	8	6.5	6.27
	24. Fostering of technical and appraisal professionals	4	5.3	7	6	7.5	9	6.0	6.46
	25. Competence in cultivating the capacity of technical and R&D personnel	5	6.2	8	7	8.6	10	7.2	7.47
Procurement and infrastructure	26. Governmental incentives	5	6.3	8	8	8.4	10	7.6	7.35
	27. Financing competence	5	6.6	8	8	8.7	10	7.9	7.65
	28. Laws and regulations	5	6.2	7	7	8.6	10	7.3	7.40
	29. Competence in acquiring the infrastructure of biotechnology	5	5.6	8	7	8.4	10	7.2	7.50
	30. Policies for establishing a good product certification system	5	5.7	8	6	8.2	10	7.1	6.98
	The threshold value				7.15				

Source of data: this study

Notes: The gray area represents the removed assessment criteria

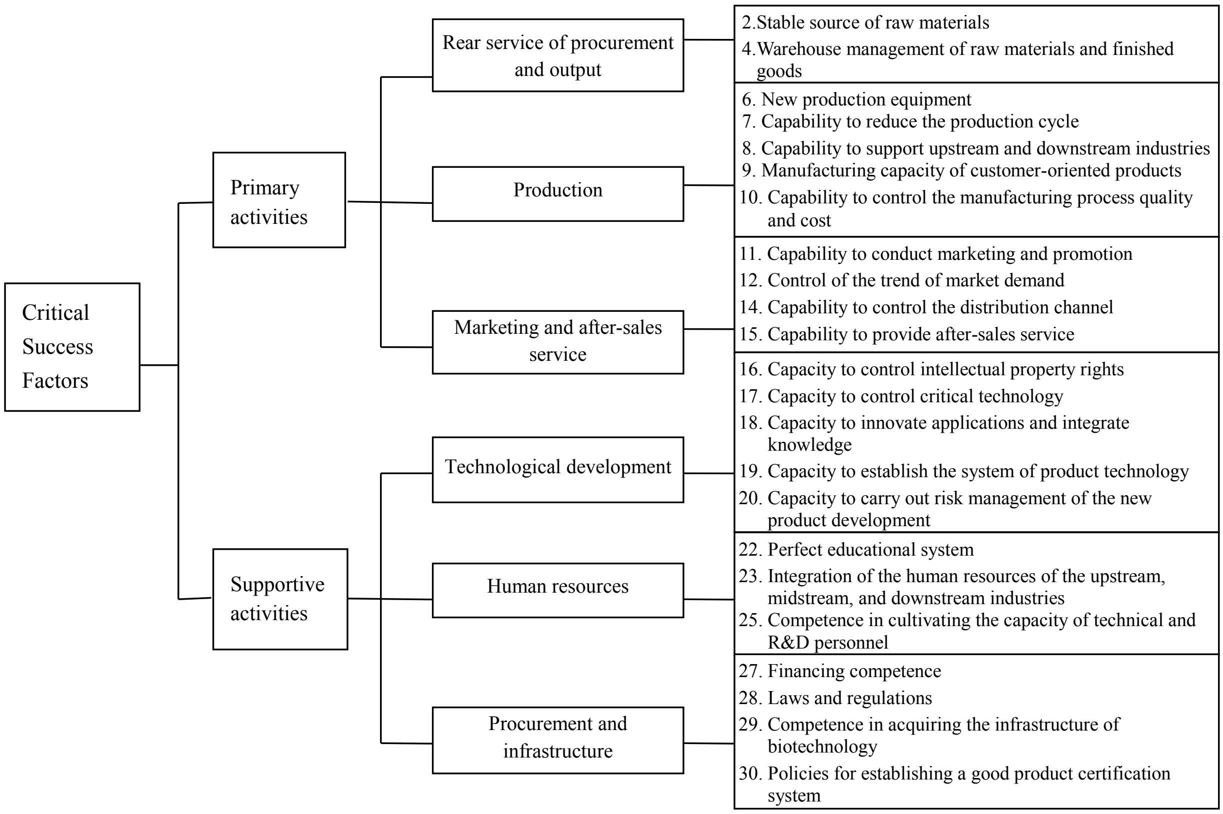

Figure 2. The strategic hierarchical structure of the critical success factors influencing the cross-domain transformation of the agriculture biotechnology industry

Source of data: this study

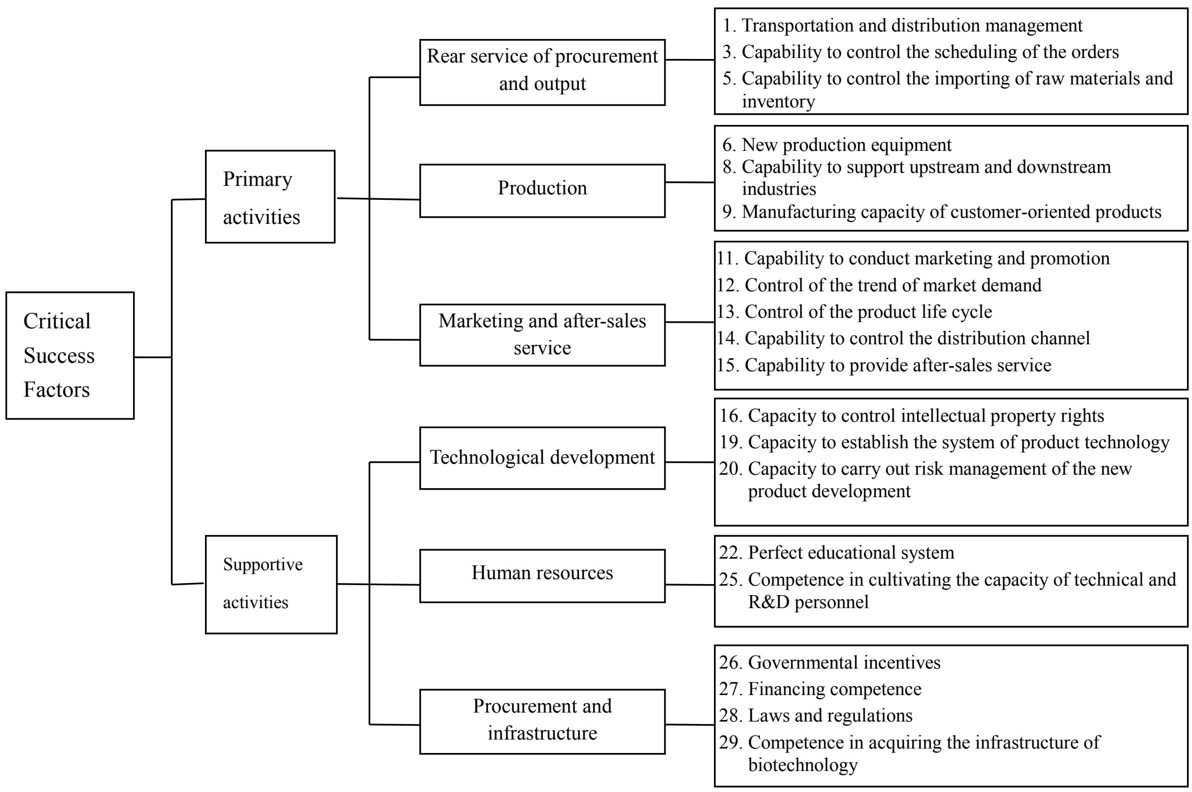

Figure 3. The strategic hierarchical structure of the critical success factors influencing the non-cross-domain transformation of the agricultural biotechnology industry

Source of data: this study

and non-cross-domain transformation, which are 7.35 and 7.15, respectively. The thresholds values are the standards for the selection of the assessment criteria of the critical success factors (the selection results are shown in Tables 2 and 3). In the aspects of both the cross-domain and the non-cross-domain transformation, this study selects 23 and 20 highly important assessment criteria. According to the selection results, the authors construct the strategic hierarchical structure of the critical success factors influencing the cross-domain and non-cross-domain transformation of the agriculture biotechnology industry (Figures 2 and 3), which form the basis for the design of the FANP expert questionnaire in the second stage.

The second-stage FANP questionnaire survey

In accordance with the FANP computation procedures as described in the above sections and based on the Excel and the Super Decisions software, the study deals with the second-phase expert questionnaire. First, the authors use the triangular fuzzy arithmetic to establish a fuzzy positive reciprocal matrix as the basis for the computation of fuzzy weights. Furthermore, in line with the definite values given by the experts, they proceed with the consistency test. The test results demonstrate that the C.I. (consistency index) value and the C.R. (consistency ratio) values of the cross-domain and the non-cross-domain transformation are both ≤ 0.1, which is consistent with the suggested acceptable range (Saaty 1980). That is to say, the overall judgments made by the experts regarding the criteria of all the levels are consistent. The analysis of the overall assessment shows that the C.R.H. (consistency ratio hierarchy) values of the cross-domain and the non-cross-domain transformation are 0.07 and 0.05, respectively, which is consistent with the suggested acceptable range of < 0.1. That means the strategic level structure built by this study shows appropriate and connective allocations. Thus, the analysis in the next step for the further computation of the local priority of the critical success factors on different levels can proceed; it later results in the super matrix, which goes a step further in computing the global priority of all the levels to ensure a definite weight for the different critical success factors in the overall structure. Finally, considering the research goal of constructing the critical success factors that influence the transformation of the agricultural biotechnology industry and based on the sorting of the priorities, this study discovers the critical factors for the assessment of the influential factors that the experts emphasized; the analytical results are shown in Tables 4 and 5.

The critical factors influencing the cross-domain transformation of the agricultural biotechnology industry in Taiwan

The results of the sorting of the importance levels of the critical success factors in the last row of Table 4 indicate the fact that the experts consider the most important critical success factors (with the highest weight of 0.136) among the 23 items for assessment in the third level to be "a stable source of raw materials;" the factor with the second-highest importance level is the "control of the trend of market demand (0.064);" and the factors with the third to the tenth priorities are sequentially "new production equipment (0.057)"; "capability to support upstream and downstream industries (0.056)"; "integration of the human resources of the upstream, midstream, and downstream industries (0.053)"; "capability to conduct marketing and promotion (0.050)"; "capacity to control critical technology (0.046)"; "capability to reduce the production cycle (0.045)"; "capability to control the manufacturing process quality and cost (0.044)" and "manufacturing capacity of customer-oriented products (0.043)". Of these 10 weighted assessment items, 8 belong to the primary activities and 2 are supportive activities.

Daniel (1961) suggested that most industries normally have three to six critical success factors. Therefore, the authors decided to select the six most important critical success factors (see Table 4) as the key factors influencing the cross-domain transformation of the agricultural biotechnology industry in Taiwan. These six factors are sequentially: "a stable source of raw materials", "control of the trend of market demand", "new production equipment", "capability to support upstream and downstream industries", "integration of the human resources of the upstream, midstream, and downstream industries" and "capability to conduct marketing and promotion".

The critical factors influencing the non-cross-domain transformation of the agricultural biotechnology industry in Taiwan

From the bottom row of Table 5, we can see that the experts consider the most important (with a high importance level) critical successes factors of the 20 evaluative items of the third level of the non-cross-domain transformation to be (sequentially from the most important to the least important) "capacity to establish the system of product technology (0.157)"; "capacity to control intellectual property rights (0.150)"; "perfect educational system (0.135)"; "capacity to carry out risk management of the new product development (0.121)"; "competence in culti-

Table 4. The sorting results of the importance level of the critical success factors that influence the cross-domain transformation of the agricultural biotechnology industry

First level		Second level		Third level		
Dimension	weights	assessment criteria	weights	assessment criteria	weights	sorting results on the importance level
Primary activities	0.608	Rear service of procurement and output	0.175	Stable source of raw materials	0.136	1
				Warehouse management of raw materials and finished goods	0.039	15
		Production	0.245	New production equipment	0.057	3
				Capability to reduce the production cycle	0.045	8
				Capability to support upstream and downstream industries	0.056	4
				Manufacturing capacity of customer-oriented products	0.043	10
				Capability to control the manufacturing process quality and cost	0.044	9
		Marketing and after-sales service	0.188	Capability to conduct marketing and promotion	0.050	6
				Control of the trend of market demand	0.064	2
				Capability to control the distribution channel	0.042	11
				Capability to provide after-sales service	0.032	17
Supportive activities	0.392	Technological development	0.193	Capacity to control intellectual property rights	0.027	19
				Capacity to control critical technology	0.046	7
				Capacity to innovate applications and integrate knowledge	0.039	14
				Capacity to establish the system of product technology	0.041	12
				Capacity to carry out risk management of the new product development	0.040	13
		Human resources	0.121	Perfect educational system	0.037	16
				Integration of the human resources of the upstream, midstream, and downstream industries	0.053	5
				Competence in cultivating the capacity of technical and R&D personnel	0.031	18
		Procurement and infrastructure	0.078	Financing competence	0.017	23
				Laws and regulations	0.018	22
				Competence in acquiring the infrastructure of biotechnology	0.019	21
				Policies for establishing a good product certification system	0.024	20

Source of data: this study

vating the capacity of technical and R&D personnel (0.092)"; "laws and regulations (0.041)"; "financing competence (0.039)"; "competence in acquiring the infrastructure of biotechnology (0.034)"; "capability to control the scheduling of the orders (0.028)" and "capability to control the importing of raw materials and inventory (0.023)", of which 2 belong to primary activities and 8 to supportive activities.

Following Daniel's (1961) suggestion that most industries normally have three to six critical success factors, the authors decided to select the six most important critical success factors (see Table 5) as the key factors influencing the non-cross-domain transformation of the agricultural biotechnology industry in Taiwan. These six factors are sequentially: "capacity to establish the system of product technology"; "capacity to control intellectual property rights"; "perfect educational system"; "capacity to carry out risk management of the new product development"; "competence in cultivating the ca-

Table 5. The sorting results of the importance level of the critical success factors that influence the non-cross-domain transformation of the agricultural biotechnology industry

First level		Second level		Third level		
Dimension	weights	assessment criteria	weights	Assessment criteria	weights	sorting results on the importance level
Primary activities	0.211	Rear service of procurement and output	0.065	Transportation and distribution management	0.014	19
				Capability to control the scheduling of the orders	0.028	9
				Capability to control the importing of raw materials and inventory	0.023	10
		Production	0.058	New production equipment	0.015	18
				Capability to support upstream and downstream industries	0.021	13
				Manufacturing capacity of customer-oriented products	0.022	11
		Marketing and after-sales service	0.088	Capability to conduct marketing and promotion	0.018	16
				Control of the trend of market demand	0.020	14
				Control of the product life cycle	0.018	17
				Capability to control the distribution channel	0.011	20
				Capability to provide after-sales service	0.021	12
Supportive activities	0.789	Technological development	0.428	Capacity to control intellectual property rights	0.150	2
				Capacity to establish the system of product technology	0.157	1
				Capacity to carry out risk management of the new product development	0.121	4
		Human resources	0.228	Perfect educational system	0.135	3
				Competence in cultivating the capacity of technical and R&D personnel	0.092	5
		Procurement and infrastructure	0.133	Governmental incentives	0.019	15
				Financing competence	0.039	7
				Laws and regulations	0.041	6
				Competence in acquiring the infrastructure of biotechnology	0.034	8

Source of data: this study

pacity of technical and R&D personnel" and "laws and regulations".

The critical success factors influencing the differences between the cross-domain and non-cross-domain transformation of the agricultural biotechnology industry in Taiwan and their implications

From Table 6, we can see that most of the critical success factors influencing the cross-domain transformation of the agricultural biotechnology industry in Taiwan are covered by the dimension of primary activities. This means that the agricultural biotechnology industries that expect to have a cross-domain type of transformation need: manufacturers that provide them with stable and good-quality raw materials, the ability to control the trend of market demand, a new production equipment to increase productivity, the capabilities to produce new products, support upstream and downstream industries, integrate with strengthened human resources, conduct marketing and promotion, and the control critical technology, so that the cross-domain transformation can be undertaken successfully. In addition, most of the non-cross-domain factors influencing the transformation of the agricultural biotechnology industry in Taiwan fall into the dimension of supportive activities. This means that the successful non-cross-domain transformation of the agricultural biotechnology industry depends on the critical factors of: establishment of a high capacity to establish the system of product technology, effectively controlling intellectual property rights,

Table 6. The differences in the critical success factors influencing the non-cross-domain and cross-domain transformation of the agricultural biotechnology industry

The sorting results on the importance level	Cross-domain	Non-cross-domain
	critical success factor	critical success factor
1	Stable source of raw materials	Capacity to establish the system of product technology
2	Control of the trend of market demand	Capacity to control intellectual property rights
3	New production equipment	Perfect educational system
4	Capability to support upstream and downstream industries	Capacity to carry out risk management of the new product development
5	Integration of the human resources of the upstream, midstream, and downstream industries	Competence in cultivating the capacity of technical and R&D personnel
6	Capability to conduct marketing and promotion	Laws and regulations

Source of data: this study

substantially operating a perfect educational system for employees, the risk management of the new product development, and the competence in cultivating the capacity of technical and R&D personnel. Finally, the government should enact laws and regulations that support the successful transformation activities of the agricultural biotechnology industries.

CONCLUSION

Through reviewing and receiving the inspiration from the literature and based on the value-chain perspective, this study forms 30 critical success factors that influence the non-cross-domain and the cross-domain transformation of the agricultural biotechnology industry, and establishes the initial FANP in order to facilitate the subsequent empirical research. Furthermore, utilizing the bi-triangular fuzzy arithmetic of the fuzzy Delphi method, this study selects the criteria for assessment. After the selection, it retains 23 and 20 assessment criteria for the critical success factors with a high importance level according to the expert consensus, respectively, for the cross-domain and the non-cross-domain transformation. Finally, the FANP results show that the critical success factors that influence the cross-domain transformation are sequentially: a stable source of raw materials; control of the trend of market demand; a new production equipment; the capability to support upstream and downstream industries; the integration of the human resources of the upstream, midstream, and downstream industries; the capability to conduct marketing and promotion, and the like. Most of these cross-domain factors focus on the primary activity dimension. The critical success factors that influence the non-cross-domain transformation are sequentially: the capacity to establish the system of product technology; the capacity to control intellectual property rights; a perfect educational system; the capacity to carry out risk management of the new product development; the competence in cultivating the capacity of the technical and R&D personnel; laws and regulations; and so on, which mostly come under the dimension of supportive activities.

With this study, we can see that the proprietors of the agricultural biotechnology industry who wish to transform their business in the cross-domain form need to have stable and qualified manufacturers and sources of raw materials, to be able to control the trend of market demand, to have a new production equipment to increase productivity and to generate new products, to have good capabilities to support upstream and downstream industries and to integrate with the human resources of the upstream, midstream, and downstream industries, to have a great capability to conduct marketing and production, and so on. On the other hand, the proprietors of the agricultural biotechnology industry who wish to transform their business according to the non-cross-domain form need to have the capacity to establish the system of product technology; the capacity to control the intellectual property rights; a perfect educational system; the capacity to carry out risk management of the new product development; the competence in cultivating the capacity of the technical and R&D personnel; a good control of the law and regulation system, and so on. Proprietors who can control the directions well (the assessment criteria that emerge from the research result of this study) are able to facilitate the transformation of their agricultural biotechnology business. These critical success factors are able to guide the proprietors to plan and practice effectively the assigned procedures as directed by the critical success factors. Therefore, the proprietors are able not only to achieve their set goals, but also to acquire sustainable competitive advantages in such a competitive business environment, and thus to reach their goal of sustainable operation of their businesses.

REFERENCES

Aaker D.A. (2009): Strategic Market Management. 9th ed. John Wiley and Sons, New York.

Adrian J.S. (1996): Value Migration: How to Think Several Moves Ahead of the Competition. The President and Fellows of Harvard College, Boston.

Arojarvi O. (2001): How to Value Biotechnology Firms: A Study of Current Approaches and Key Value Drivers. Helsinki School of Economics and Business Administration. The President and Fellows of Harvard College, Boston.

Bibeault B.D. (1982): Corporate Turnaround: How Managers Turn Losers into Winners. McGraw-Hill Book Company, Boston.

Buckley J.J. (1985): Fuzzy hierarchical analysis. Fuzzy Sets and Systems, *17*: 233–247.

Büyüközkan G., Ertay T., Kahraman C., Ruan D. (2004): Determining the importance weights for the design requirements in the house of quality using the fuzzy analytic network approach. International Journal of Intelligent Systems, *19*: 443–461.

Cheng J.H. (2001): Indexes of competitive power and core competence in selecting Asia-Pacific ports. Journal of the Chinese Institute of Transportation, *13*: 1–25.

Cheng M.Z. (1996): Business transformation strategy and keys to success. Trade Weekly, *1690*: 18–21.

Croteau A., Li P. (2003): Critical success factors of CRM technological initiatives. Canadian Journal of Administrative Sciences, *20*: 21–35.

Daniel D.R. (1961): Management information crisis. Harvard Business Review, *39*: 111–121.

Fearne A., Hughes D. (1999): Success factors in the fresh produce supply chain: Insights from the UK. Supply Chain Management, *4*: 120–131.

Hofer E., Schendel R. (1985): Strategic Management and Strategic Marketing: What's Strategic about Either One, Strategic Marketing and Management. John Wiley and Sons, New York.

Hsu T.H. (1998): The fuzzy Delphi analytic hierarchy process. Journal of the Chinese Fuzzy Systems Association, *4*: 59–72.

Hwang C.L., Lin M.J. (1987): Group Decision Making Under Multiple Criteria: Methods and Applications. Springer-Verlag, New York.

Lee M.S. (2008): Critical success factors for intra-disciplinary transformation of the agricultural biotechnology industry in Taiwan based on the value chain concept. Journal of Economics and Management, *4*: 65–88.

Lee M.S., Lu S.I., San Y.H., Kuo Y.C., Hsu Y.C. (2007): The critical success factors cross-domain transformation of medium and small enterprise from the value chain point of view – A case study of semiconductor manufacturing. Journal for SEM Development, *3*: 17–41.

Lin L.Z. (2006): A Fuzzy ANP-Based Approach to Brand Life Cycle Management: An Application for Department Store. [Dissertation for the Degree of Doctor.] National Kaohsiung First University of Science and Technology in Partial Fulfillment of the Requirements, Yenchao, Kaohsiung, Taiwan.

Lin Y.H., Wann J.W., Lu T.J. (2009): The study of transforming manufacturing firms into service-oriented business: An SSME perspective. Journal of Technology Management, *14*: 59–96.

Löffler A. (2002): Trends in biotechnology: Implications for the pharmaceutical industry. International Journal of Medical Marketing, *2*: 345–348.

Lofsten H., Lindelof P. (2003): Determinants for an entrepreneurial milieu: Science parks and business policy in growing firms. Technovation, *23*: 51–64.

Porter M.E. (1985): Competitive Advantage. The Free Press, New York.

Robbins S.P. (1994): Management. Prentice Hall Inc., New Jersey.

Rockart J.F. (1979): Chief executives define their own date needs. Harvard Business Review, *57*: 81–93.

Saaty T.L. (1980): The Analytic Hierarchy Process. McGraw-Hill, New York.

Saaty T.L. (1996): Decision Making with Dependence and Feedback: The Analytic Network Process. RWS, Pittsburgh.

Saaty T.L. (2006): Rank from comparisons and from ratings in the analytic hierarchy/network processes. European Journal of Operational Research, *168*: 557–570.

Sun Z.L. (2006): The bio-economy: The coming of the era. Taiwan Economic Research Monthly, *29*: 14–21.

Thompson A.A., Strickland III A.J., Gamble J.E. (2010): Crafting and Executing Strategy, 17th ed. McGraw-Hill/Irwin, New York.

Arrived on 28th March 2011

Contact address:

Meng-Shiunn Lee, Department of Business Administration, Chang Jung Christian University, No. 396, Chang Jung Rd, Kway Jen, Tainan, 71101, Taiwan, R.O.C.; e-mail: meng@mail.cjcu.edu.tw