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Full Length Research Paper

The significance of research and development (R&D) and innovation to high-tech industry from the total quality management (TQM) perspective

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Despite the national quality awards (NQAs) categories that reflect properly the total quality management (TQM) concept, the relative importance of these evaluation criteria may have different influence on different industries due to various characteristics of industries. Therefore, this research makes an attempt on probing the impact of each Taiwan National Quality Awards (TNQA) evaluation category, particularly, "research and development (R&D) and innovation," for the high-tech industry. Based on TNQA evaluation criteria, the research builds up a hierarchical structure of evaluation standards and designs a questionnaire for soliciting expert opinions from industries, government, and academia. Fuzzy analytic hierarchy process (FAHP) is then employed to compute the weights of TNQA categories and criteria in an effort to identify the critical features high-tech firms need to develop and reinforce to excel in a changing industry teeming with intensive competition. Of the eight TNQA evaluation categories, experts consulted by the study demonstrate the consensus that the weighted value of "R&D and innovation" appears to be significantly higher than the weight it receives in the TNQA evaluation standard, suggesting that, in addition to competent leadership and management, research and development capability also plays a crucial role to help high-tech firms promote innovation and enhance core competitiveness.

Key words: High-tech industry, national quality award (NQA), total quality management (TQM), evaluation criteria, fuzzy analytic hierarchy process (FAHP).

INTRODUCTION

To pursue sustainable business development in a rapidly changing industry environment, an enterprise has to be able to grasp and respond to the latest market trends in a timely manner so as to keep securing a steady growth (Alam, 2009a; Alam et al., 2010a). Traditional management system is no longer capable of meeting the demands of today's changing environment. Reformations and adjustments need to be initiated to build up a quality control system to enhance a firm's competitiveness and get it prepared for tacking future challenges (Alam et al., 2010b). In response to the trend of globalization and the continuing advancement of technology, traditional Industries are increasingly replaced by high-tech industries (Alam, 2009b). In the age of knowledge economy, the technology- and cost-intensive high-tech industries have formed the brightest constellation in the firmament of global business. Successful research and development (R&D) of innovative products or services accordingly become the guarantee of profits and fortunes (Chen et al., 2006; Lin et al., 2006).

A business's competitive advantages lie in innovation and speed; product research and development is of crucial importance in keeping a firm competitive; it is also a major source empowering a firm to create its competitive advantages (Alam and Khalifa, 2009). Modern firms should therefore pay close attention to develop

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forward-looking, farseeing strategies for product development and innovation, implement effective R&D management, and increase R&D output (Guan et al., 2006; Kakati, 2003). A management system is therefore required to help R&D and innovation activities run at full throttle and produce maximum results in the knowledge- and technology-intensive high-tech industry. In other words, recognition of the importance of R&D on business competitiveness and performance should prompt a firm to launch a management system for planning, tracking, reporting and evaluating its R&D projects in a manner that best meet its needs (Chen and Huang, 2004; Kafouros et al., 2008). To keep up their competitive advantages, many firms have adopted the total quality management (TQM) model to integrate internal operations with product and service processes and to facilitate all-encompassing business management geared to achieve of goal of thorough cost control (Juran and Gryna, 1988; Powell, 1995). While R&D and innovation are important, firms need to adopt and change their management models in response to the changing environment so as to promote business performance and reduce operating costs. As a result, in aid of organizations in TQM implementation to improve products and service quality, several national quality awards (NQAs) including Malcolm Baldrige national quality award (MBNQA) in the USA, European foundation for quality management (EFQM) in Europe, and Deming prize in Japan and so forth, developed in many quality-promoting countries have been increasingly adopted as foremost self-assessment models for better performance by numerous organizations (Chuan and Soon, 2000; Conca et al., 2004).

The central purpose of NQA is to expedite industrial upgrading and enhance national competitiveness by encouraging positive competition among enterprises. However, high-tech industry is quite different from other industries; different industrial features may lead to different operation and management models (Baden-Fuller and Morgan, 2010; Calia et al., 2007; Chorev and Anderson, 2006; Wikström et al., 2010). In other words, despite the assigned weights of each NQA categories that reflect properly the TQM principles, the relative importance of the NQA evaluation criteria may have different importance for different industries due to diverse characteristics of industries (Hendricks and Singhal, 2001; Pun, 2002). NQAs should therefore take into consideration the differences between industries in allocating weights to its evaluation criteria. A universal set of evaluation standards with each criterion assigned a fixed weight is both inapplicable and unfair as it fails to accommodate the unique features of different industries. Firms are prompted to make winning their solid objectives, and the original purpose of NQA remains unfulfilled (Curkovic and Handfield, 1996; Shergold and Reed, 1996; Wu et al., 1997).

Therefore, on the one hand, based primarily on the evaluation standards of the Taiwan National Quality Award (TNQA) that encompasses the TQM philosophy as the other NQAs, the study aims to establish a hierarchical evaluation structure of quality management and accordingly perform an in-depth examination on the weight allocation of TNQA evaluation categories with a special focus on the high-tech industry. On the other hand, while R&D and innovation, one of the TQM crucial elements, is an independent evaluation category of the TNQA model (CSDC, 2007), little research has been done in debating its importance particularly for the high-tech industry. As a result, the study makes a specific attempt on probing the impact of the TNQA evaluation category, R&D and innovation, on the high-tech industry.

The fuzzy set theory proposed by Zadeh (1965), an important concept applied in the scientific environment, has been available to other fields such as control engineering, artificial intelligence, management science, and multiple criteria decision making (MCDM) among others (Bellman and Zadeh, 1970). In a real world, there exist “ambiguity” and “vagueness” that represent some degree of uncertainty of human thoughts. In addition, analytic hierarchy process (AHP) has been widely applied in various areas to deal with decision-making problems such as multiple criteria evaluation/selection of alternatives (Saaty, 1994, 1996). And the analytical results by using AHP with the consensus method of the expert group in handling unquantifiable/qualitative criteria have been considered quite reliable (Condon et al., 2003; Korhonen and Voutilainen, 2006). The concept of combining the fuzzy theory and AHP is referred to as fuzzy AHP (FAHP) that should be able to tolerate fuzziness during decision-making process and appropriately reflect human intellection. Several practicable applications of utilizing FAHP in criteria evaluation and alternatives selection have been demonstrated in previous studies (Bayazit and Karpak, 2007; Chiou and Tzeng, 2002; Chiou et al., 2005; Chiu et al., 2006; Ding, 2010; Hsieh et al., 2004; Lee et al., 2008; Pepiot et al., 2008; Soh, 2010; Wang and Chang, 2007; Wu and Lee, 2007). Accordingly, this study adopted the FAHP method to obtain professional's opinions and analyze the relative weights of the criteria significant to the high-tech industry which are then compared to their counterparts in the TNQA evaluation. Criteria under the category of “R&D and innovation” are separately analyzed to facilitate an understanding of the crucial role of R&D and innovation in high-tech industries and to provide high-tech firms a basis for reviewing the allocation of their corporate resources.

HIGH-TECH INDUSTRIES AND ITS RELATIONSHIP WITH R&D AND INNOVATION

There is no universally accepted definition of “high-tech” (alternatively “hi-tech”), nor is there a typical list of industries considered to be high-tech. Generally speaking, “high-tech” industries have three common characteristics, strong scientific-technical base, new technologies quickly replacing the old ones, and applications of advanced technologies for creating markets and requirements (Shanklin and Ryans, 1984, 1987). Yehuda (1997) suggests three criteria for the classification issue: more than 10% of employees with a university degree, more than 5% of investment in research and development, and leading and uniqueness of the area of activity of the organization in the industrial sector. In essence, there is lack of thorough description for so-called high-tech companies. However, in the light of the preceding definitions by the related studies (Boretsky, 1982; David, 1982; Kelly, 1977), the term “high-tech” normally indicates advanced computer systems, information technologies, communications, sophisticated network systems and so forth.

Innovation, especially for high-tech companies, has been regarded as crucial impetus for corporate profitability and growth in today's keenly competitive environments. To forecast accurately the development of the innovation factor becomes a key issue. The research conducted by Guan et al. (2006) adopted innovation ratio (IR) expressed as the number of innovative products divided by the number of total products as the measurement variable of innovation performance. More recently, the term scoreboard associated with science, technology, and innovation (STI) indicators that are updated on a regular basis is used to evaluate and benchmark the performance of their national industries and analyze their key drivers (Grupp and Stadler, 2005). Besides, the intent of the scoreboard is to boost greater effective investment in R&D as part of the innovation process. R&D capability is one of the most important assets that can affect development of survival of enterprises for the high-tech industries (Davis and Botkin, 1994). Therefore, recently, in response to dynamically changing environ-ment, an increasing number of high-tech firms have been devoting more and more to R&D and innovative pro-cesses for competitive strategies (Chorev and Anderson, 2006; Kakati, 2003; Smith and Reece, 1999; Teece, 2010).

According to the prior studies, it has shown that in the long term, a country’s international competitiveness is determined by the ability of utilizing technology. In other words, encountering the advent of knowledge economy, advanced nations recognize the central importance of scientific and technological development to overall competitiveness (Alam, 2009b). This implies that the capability of R&D and innovation plays more vital role than before since it can help organizations, especially high-tech firms, fit in the niche in global rival marketing for improving the economy of a nation (Guan et al., 2006). As a result, in the trend towards innovative quality-conscious promotion, for high-tech firms, R&D and innovation is assumed to be one of the most important elements that should be specifically underlined while implementing TQM, the foremost quality movement that has been applied worldwide for promoting organizational performance successfully by various industries across many countries.

TQM AND THE TNQA CRITERIA

Here, the philosophy of total quality management (TQM) and the evaluation criteria of Taiwan National Quality Award (TNQA) followed by a summary of important TQM-related research are described respectively.

Total quality management (TQM)

In today’s market characterized by ever-mounting competition, firms need to introduce quality products and services to satisfy the needs of consumers. Only constant promotion of product quality and management capability can keep a company in sustainable development. In response to the growth in consumers’ demand for quality, firms should implement a quality management system to meet the expectations from the general public. TQM is found as a management approach for an organization, evolving around quality-oriented customer satisfaction and aiming to embed awareness of quality at the center of a comprehensive management system encompassing all organizational process, such as management information system, enterprise resource planning system, after-sales service management, and customer relationship management (Agus and Abdullah, 2000; Chin et al., 2003; Chong and Rundus, 2004; Motwani, 2001; Wadsworth et al., 2002). In other words, TQM is a systemic method based on the concept of precaution, involving the participation of all the members in an organization, and employing scientific methods to constantly improve operation, management, product development, service delivery, and other organizational processes so as to generate optimal competitiveness and secure long-term success by ensure present and future customer satisfaction (Keogh,1994). TQM underlines three major principles: customer-orientation, total participation of all employees, and constant improvements (Selladurai, 2002). Its main spirit lies in utilizing the organization’s human resources, using teamwork and adopting quality assurance techniques and improvement methods to facilitate ongoing advancement in product/service quality, customer satisfaction, and business performance. It is therefore obvious that, to any firm, TQM implementation is an essential key to sharpen competitive edge, provide quality products and services, and ensure customer satisfaction (Chan and Quazi, 2002; Chong and Rundus, 2004; Nilsson et al., 2001; Reed et al., 2000). For instance, more recently, Yeh and Lin (2010) proposed a V-shape performance evaluation model to diagnose the

TQM implementation in the semiconductor industry in Taiwan. Duric et al. (2010) developed a set of key performance indicators of process performance, as key element of the quality management system based on TQM, in a joint-stock company.

With the collective efforts of local firms, TQM has been extensively implemented to produce outstanding results. Moreover, the competitiveness of an enterprise depends on the trinity of capital, strategy, and management, and management reigns as the top element of business competitiveness. Establishment of a solid and superior management mechanism is thus imperative for firms striving for steady business growth and sustainable development. Fortunately, the Taiwan National Quality Award (TNQA) provides a valuable opportunity and incentive encouraging local firms to build and evaluate their quality management systems (Su et al., 2003).

Taiwan National Quality Award (TNQA)

Since 1990, the Taiwan National Quality Award (TNQA) based on the criteria of the MBNQA, EFQM excellence model, and Deming prize, and ISO9000:2000, the highest honor granted to quality in Taiwan, is presented with the purpose to upgrade the product/service quality of enterprises in Taiwan as well as to promote the country's overall competitiveness in the global market (Su et al., 2003). Winning the TNQA signifies a paradigm of thorough and successful TQM implementation, and meeting the TNQA evaluation standards indicates the presence of a comprehensive quality management mechanism in an enterprise and highlights an excellent corporate image.

The details of the TNQA categories and criteria are summarized in Table 1 (CSDC, 2007). The TNQA contains eight categories and 33 criteria that embody the most important elements of TQM, with a total score of 1000 points. "8.0 overall performance" with a score of 250 points (0.25) is the leading category followed by "1.0 leadership and management philosophy" with a score of 250 points (0.16). "3.0 R&D and innovation" has a score of 90 points (0.09) that is the least important TNQA category.

To put the TNQA purpose and ideas into practice is to establish an integrated, all-round management system and to guarantee business profit. TNQA evaluation criteria are developed based on five major guidelines summarized as follows (CSDC, 2007):

1) General applicability: The TNQA evaluation criteria, instead of catering to specific industries, are generally applicable to every business and industry. Firms are eligible to apply for evaluation regardless of their industries.
2) Farseeing vision: The TNQA has its evaluation criteria reflected the contemporary trends so as to chart the directions of future developments for local enterprises and to encourage them to grasp the trends and pursue ongoing improvements with forward-looking measures and farseeing visions.
3) Comprehensive integration: The TNQA evaluation criteria incorporate eight major categories embodying the core concepts of TQM that emphasizes the quest for excellence in planning, managing, monitoring, and evaluating every organizational process. The eight categories are inter-related and need to be implemented in a comprehensive manner so as to create concrete and optimal values for enterprises.
4) International perspective: The TNQA evaluation criteria are developed by emulating their counterparts adopted by similar awards in other countries with the hope to elevate its status to a global level and to foster in the participants an international perspective.
5) Perfect practicability: All TNQA evaluation criteria are perfectly practicable in assisting organizations to enhance efficiency, improve productivity, elevate performance, augment results, and pursue excellence. They can be further adopted as a set of learning benchmarks to help organizations build and implement an exemplary comprehensive management model.

Implementation of TQM in Taiwan has been proved to generate fine results, and the government has worked with great vitality to help enterprises build up quality management systems. As a showcase of the government's efforts, TNQA is held to raise quality awareness in enterprises and to promote the implementation of TQM as a powerful approach to sharpen competitive edges. For the benefits of enterprises, quality management should be treated as a major goal that merits substantial investment and constant efforts. However, a quality management system may not work or its implementation can fail without careful and comprehensive planning in advance. Enterprises will be able to save considerable time and resources in learning and experimenting with the quality management system if there is a model to emulate, and TNQA is established exactly in compliance with the concept of TQM as its scope covering all the major elements essential for successful TQM performance which are outlined as follows:

i. Leadership of the executive management, management philosophy, and decision-making model.
ii. Management performance, strategic planning and their implementation and evaluation.
iii. Customer and market development; implementation of customer-oriented marketing strategies, attention to the establishment of solid customer relationships.
iv. Emphasis on product/technology research and development; implementation of innovative RandD management.
v. Establishment of a comprehensive information system; tracking market trends on a real-time basis to promote business performance; development of fully automatic

Table 1. Taiwan National Quality Award (TNQA) evaluation categories and criteria.

Categories/criteria	**Points (weights)**
1.0 Leadership and management philosophy 1.1 Management philosophy and value 1.2 Organization's missions and visions 1.3 Leadership of executive management 1.4 Creation of total quality culture 1.5 Corporate social responsibility	160(0.16)
2. 0 Strategic management 2.1 Overall strategic planning 2.2 Management model 2.3 Strategy execution and improvement	90(0.09)
3. 0 R&D and innovation 3.1 R&D/innovation strategy and process 3.2 R&D/innovation investment 3.3 R&D/innovation result evaluation	90(0.09)
4.0 Customer and market development 4.1 Product/service and market strategy 4.2 Customer and business intelligence management 4.3 Customer relationship management	100(0.10)
5.0 Human resources/knowledge management 5.1 Human resources planning 5.2 Human resources development 5.3 Human resources application 5.4 Employee relationship management 5.5 Knowledge management	130(0.13)
6.0 Information strategy and management 6.1 Information strategy planning 6.2 Network application 6.3 Information application	90(0.09)
7.0 Process management 7.1 Product process management 7.2 Management of supporting activities 7.3 Cross-organizational relationship management	90(0.09)
8.0 Overall performance 8.1 Customer satisfaction 8.2 Market development 8.3 Financial performance 8.4 Human resources development 8.5 Information management 8.6 Process management 8.7 Innovation/core competitiveness 8.8 Social recognition (quality honors)	250(0.25)

( ) indicates the percentage that points of each category accounts for the overall 1000 points.
Source: CDSC (2007).

management platform.

vi. Attention to employee training and integration of intra-organizational knowledge to facilitate resource sharing and to cement employee loyalty.

vii. Standardization of overall organizational processes plus effective management and constant improvement to enhance process performance and reinforce management of standardized processes.

Summary of TQM-related research

Several former studies have focused mainly on empirical analyses of TQM performance by the establishment of quality management systems based on the international quality excellence awards (such as, MBNQA, EFQM, Deming prize, etc.,) (Eng and Yusof, 2003; Kunst and Lemmink, 2000; Pun, 2002; Uyar, 2008; Yoo, 2003; Zhao et al., 2004). On the other hand, among the literatures relevant to TQM, there are certain applications that use the AHP method. For instance, Madu et al. (1995) adopt the AHP to develop a decision support system (DSS) to help effectively control the cost of maintenance floats as a result of TQM implementation. Pun (2002) constructs self-assessment criteria of an integrated TQM and performance measurement (PM) using the AHP analysis. In the study conducted by Chin et al. (2002), they employed the AHP approach to prioritize the relative importance of the TQM critical factors in manufacturing industries. Dalu and Deshmukh (2002) build a multi-attributes decision model with the AHP for measuring the TQM components. And more recently, an analytic network process (ANP), a generalization of AHP, with dependence and feed-back based on Saaty's BOCR model has been utilized to assess readiness of TQM adoption and facilitate TQM implementation (Bayazit and Karpak, 2007).

In addition, some other studies are limited to explore causal relationships among TQM-related factors of the selected quality models (Eskildsen and Dahlgaard, 2000; Kaynak, 2003; Su et al., 2003; Wu and Hung, 2007). Particularly, Santos-Vijande and Ávarez-Gonález (2007) provide empirical support for the finding that TQM strongly influences firm's innovative culture and higher administrative innovation levels with a greater degree of incorporated novelty. As indicated by Prajogo and Sohal (2004, 2006), technology/R&D management has not only significant impact on quality performance, especially innovation performance, but also stronger and positive correlation with TQM. Both of these two studies have major implication that technology/R&D management is a proper resource to be used coordinately with TQM to enhance organizational innovation performance. Furthermore, the national quality award criteria can be utilized as a framework to successfully apply for R&D project assessment (Ojane et al., 2002).

Therefore, according to the related researches summarized earlier, implementing a TQM-based quality management system, fostering a quality culture, or incorporating the standardized NQA evaluation criteria into a firm's management system not only help promote business performance but also contribute to creating the synergy of quality management and organizational processes, reducing operating cost, upgrading the quality of overall corporate management, especially R&D management and innovation, to achieve business objectives.

However, little research or none discusses the suitability of the assigned weights of the TQM/NQA criteria for various industries. Although the contribution of TNQA as well as the other NQAs, in reinforcing local enterprises' commitment to quality is well recognized, and its expansion in the scope of eligibility to embrace participants from more industries is welcomed (Chuan and Soon, 2000; Su et al., 2003), the fact remains that individual industries have their own unique features. While firms from different industries may share the same spirit in their quest for quality, they may be guided by different agendas in their practice of quality management.

The TNQA authority may need to develop different evaluation standards or assign different weights to the existing criteria based on the specific features of each of the participating industry. If rendered more flexible and objective, the TNQA evaluation criteria can be expected to be more capable of and useful in guiding industries to identify priorities for improvement. High-tech industry is indeed a member in the manufacturing sector which, however, hosts other members who may have quite different concerns, needs or priorities from their high-tech counterpart in embracing quality management.

For example, in this age of shrinking profit, the business development or even survival of a high-tech firm becomes increasingly reliant on its R&D and innovation that is one of the critical factors stressed by quality practices (Huang and Lin, 2006; Miller, 1995). NQA should therefore take into consideration of the differences between industries so as to assign optimal weights to its evaluation standards.

The research thus endeavors to explore from the perspective of TQM, whether the current weight allocation of the TNQA evaluation criteria matches with the resource allocation of the high-tech industry and to identify the critical features high-tech firms need to develop and strengthen with top priority.

FUZZY ANALYTIC HIERARCHY PROCESS (FAHP)

The concepts of the fuzzy set theory and details of the fuzzy analytic hierarchy process (FAHP) are explained further.

Fuzzy set theory

The fuzzy set theory is developed for solving vagueness or ambiguities existing in decision-making process. Such a concept of fuzziness proposed by Zadeh (1965) uses mathematical models to express uncertainty of human thinking. That is, the fuzzy set theory could better embody the imprecision nature to many problems. Consequently, to obtain more representative information in decision-making process and achieve more reasonable results, the research then incorporates the fuzzy set they into AHP to evaluate the evaluation criteria of NQA by objectifying the evaluators' subjective judgments.

Fuzzy number

In the classical set theory, the truth value of a statement can be given by the membership function as $\mu_A(x)$ shown in Equation 1:

$$\mu_A(x) = \begin{cases} 1, & if\ x \in A \\ 0, & if\ x \notin A \end{cases} \quad (1)$$

Fuzzy numbers are a fuzzy subset of real numbers, and they represent the expansion of the idea of a confidence interval. According to the definition by Dubois and Prade (1980), the fuzzy number Ã is of a fuzzy set, and its membership function is $\mu_{\tilde{A}}(x)$: R → [0, 1] ($0 \leq \mu_{\tilde{A}}(x) \leqq 1$, $x \in X$), where x represents the criterion and is described by the following characteristics: (1) $\mu_{\tilde{A}}(x)$ is a continuous mapping from R (real line) to the closed interval [0, 1]; (2) $\mu_{\tilde{A}}(x)$ is of a convex fuzzy subset; (3) $\mu_{\tilde{A}}(x)$ is the normalization of a fuzzy subset, which means that there exists a

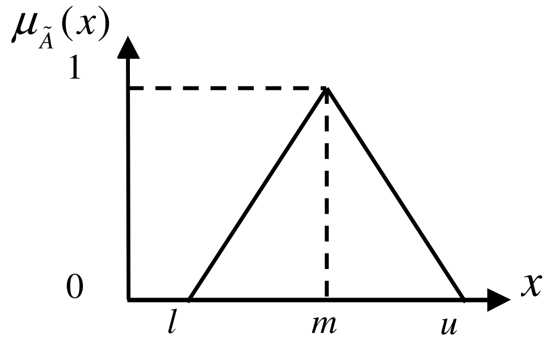

Figure 1. Membership function of the triangular fuzzy number.

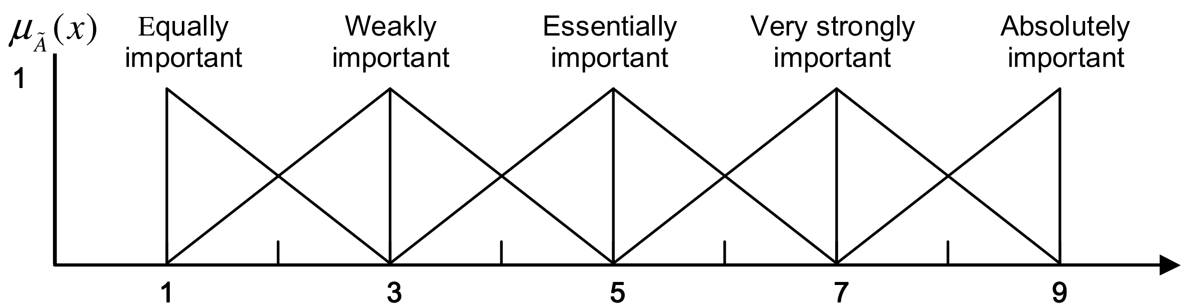

Figure 2. Membership functions of the linguistics variables for criteria comparisons.

number x0 such that $\mu_{\tilde{A}}(x_0)=1$. For instance, the triangular fuzzy number (TFN), $\tilde{A}=(l,m,u)$, can be defined as Equation 2 and the TFN membership function is shown in Figure 1:

$$\mu_{\tilde{A}}(x)=\begin{cases}(x-l)/(m-l), & \text{if } l\le x\le m\\ (u-x)/(u-m), & \text{if } m\le x\le u\\ 0, & \text{otherwise}\end{cases} \qquad (2)$$

Based on the characteristics of TFN and the extension definitions proposed by Zadeh (1975), given any two positive triangular fuzzy numbers, $\tilde{A}_1=(l_1,m_1,u_1)$ and $\tilde{A}_2=(l_2,m_2,u_2)$, and a positive real number *r*, some algebraic operations of the triangular fuzzy numbers $\tilde{A}_1$ and $\tilde{A}_2$ can be expressed as follows:

Addition of two TFNs □ :

$$\tilde{A}_1 \oplus \tilde{A}_2=(l_1+l_2, m_1+m_2, u_1+u_2) \qquad (3)$$

Multiplication of two TFNs ⊗ :

$$\tilde{A}_1 \otimes \tilde{A}_2=(l_1 l_2, m_1 m_2, u_1 u_2) \qquad (4)$$

Multiplication of any real number r and a TFN ⊗:

$$r \otimes \tilde{A}_1=(rl_1, rm_1, ru_1) \text{ for } r>0 \qquad (5)$$

Subtraction of two TFNs Θ:

$$\tilde{A}_1 \Theta \tilde{A}_2=(l_1-l_2, m_1-m_2, u_1-u_2) \text{ for } u_i>0 \qquad (6)$$

Division of two TFNs ∅ :

$$A_1 \varnothing A_2=(l_1/u_2, m_1/m_2, u_1/l_2) \qquad (7)$$

Reciprocal of a TFN:

$$\tilde{A}_1^{-1}=(1/u_1, 1/m_1, 1/l_1) \text{ for} \qquad (8)$$

Linguistic variable

Linguistic variables are variables whose values are words or sentences in a natural or artificial language. In other words, they are variables with lingual expression as their values (Hsieh et al., 2004; Zadeh, 1975). In this paper, linguistic variables expressed by TFN are adopted to stand for evaluators' subjective measures to determine the degrees of importance among evaluation criteria. The membership functions of the linguistics variables for criteria comparisons and fuzzy number and relative membership function of the linguistic scale and are shown in Figure 2 and Table 2, respectively.

Table 2. Fuzzy number and relative membership function of the linguistic scale.

Fuzzy number	Linguistic scale	TFN ($\tilde{a}_{ij}$)	Reciprocal of a TFN ($\tilde{a}_{ij}^{-1}$)
$\tilde{9}$	Absolutely important	(7, 8, 9)	(1/9, 1/9, 1/7)
$\tilde{7}$	Very strongly important	(5, 7, 9)	(1/9, 1/7, 1/5)
$\tilde{5}$	Essentially important	(3, 5, 7)	(1/7, 1/5, 1/3)
$\tilde{3}$	Weakly important	(1, 3, 5)	(1/5, 1/3, 1)
$\tilde{1}$	Equally important	(1, 1, 3)	(1/3, 1, 1)
$\tilde{2}, \tilde{4}, \tilde{6}, \tilde{8}$		Intermediate value between two adjacent judgments	

Source: Mon et al. (1994).

Fuzzy analytic hierarchy process

The analytic hierarchy process (AHP) was devised by Saaty (1994, 1996). It is a useful approach to solve complex decision problems. It prioritizes the relative importance of a list of criteria (critical factors and sub-factors) through pairwise comparisons amongst the factors by relevant experts using a nine-point scale as shown in Table 2. The fuzzy theory is incorporated into the AHP, called the fuzzy analytic hierarchy process (FAHP) (Laarhoved and Pedrycz, 1983). It generalizes the calculation of the consistent ratio (C.R.) into a fuzzy matrix. The procedure of FAHP for determining the evaluation weights are explained as follows:

Step 1: Construct fuzzy pairwise comparison matrices

Through expert questionnaires, each expert is asked to assign linguistic terms by TFN (Table 2) to the pairwise comparisons among all criteria in the dimensions of a hierarchy system. The geometric mean of all experts' opinions is computed to convert into an integrated triangle fuzzy number. The result of the comparisons is constructed as fuzzy pairwise comparison matrices ($\tilde{A}$) as shown in Equation 9.

Step 2: Examine the consistency of the fuzzy pairwise comparison matrices

According to the research of Buckley (1985a, b), it proves that if $\boldsymbol{A}=\left[a_{ij}\right]$ is a positive reciprocal matrix, then $\tilde{\boldsymbol{A}}=\left[\tilde{a}_{ij}\right]$ is a fuzzy positive reciprocal matrix. That is, if the result of the comparisons of $\boldsymbol{A}=\left[a_{ij}\right]$ is consistent, then it can imply that the result of the comparisons of $\tilde{\boldsymbol{A}}=\left[\tilde{a}_{ij}\right]$ is also consistent. Therefore, this research employs this method to validate the questionnaire:

$$\tilde{\boldsymbol{A}}=\begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix}=\begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \cdots & 1 \end{bmatrix} \quad (9)$$

Step 3: Compute the fuzzy geometric mean for each criterion

The geometric technique is used to calculate the geometric mean ($\tilde{r}_i$) of the fuzzy comparison values of criterion *i* to each criterion, as shown in Equation 10, where $\tilde{a}_{in}$ is a fuzzy value of the pair-wise comparison of criterion *i* to criterion *n* (Buckley, 1985a, b):

$$\tilde{r}_i=\left[\tilde{a}_{i1}\otimes\ldots\otimes\tilde{a}_{in}\right]^{1/n} \quad (10)$$

Step 4: Compute the fuzzy weights by normalization

The fuzzy weight of the *i*th criterion ($\tilde{w}_i$), can be derived as Equation 11, where $\tilde{w}_i$ is denoted as $\tilde{w}_i=(LW_i, MW_i, UW_i)$ by a TFN and LW_i , MW_i , and UW_i represent the lower, middle and upper values of the fuzzy weight of the *i*th criterion:

$$\tilde{w}_i=\tilde{r}_i\otimes(\tilde{r}_1\oplus\tilde{r}_2\oplus\cdots\oplus\tilde{r}_n)^{-1} \quad (11)$$

Step 5: Defuzzification

The procedure of defuzzification (Opricovic and Tzeng, 2003; Hsieh et al., 2004) locates the best nonfuzzy performance value (BNP), a crisp value, to rank the evaluation criteria. Methods used in such defuzzified fuzzy ranking generally include the mean of maximal (MOM), center of area (COA), and α-cut. Utilizing the COA method to find out the BNP is a simple and practical without the need to bring in the preferences of any evaluators. Therefore, it is used in this study. The BNP value of the fuzzy number BNP_i can be calculated by Equation 12:

$$BNP_i=[(UW_i-LW_i)+(MW_i-LW_i)]/3+LW_i \quad \forall i \quad (12)$$

Step 6: Ranking the evaluation criteria

Finally, each BNP_i is normalized by $BNP_i/\sum BNP_i$. Then the ranking of the evaluation criteria proceeds according to the normalized value.

ANALYSES AND DISCUSSIONS OF EMPIRICAL RESULTS

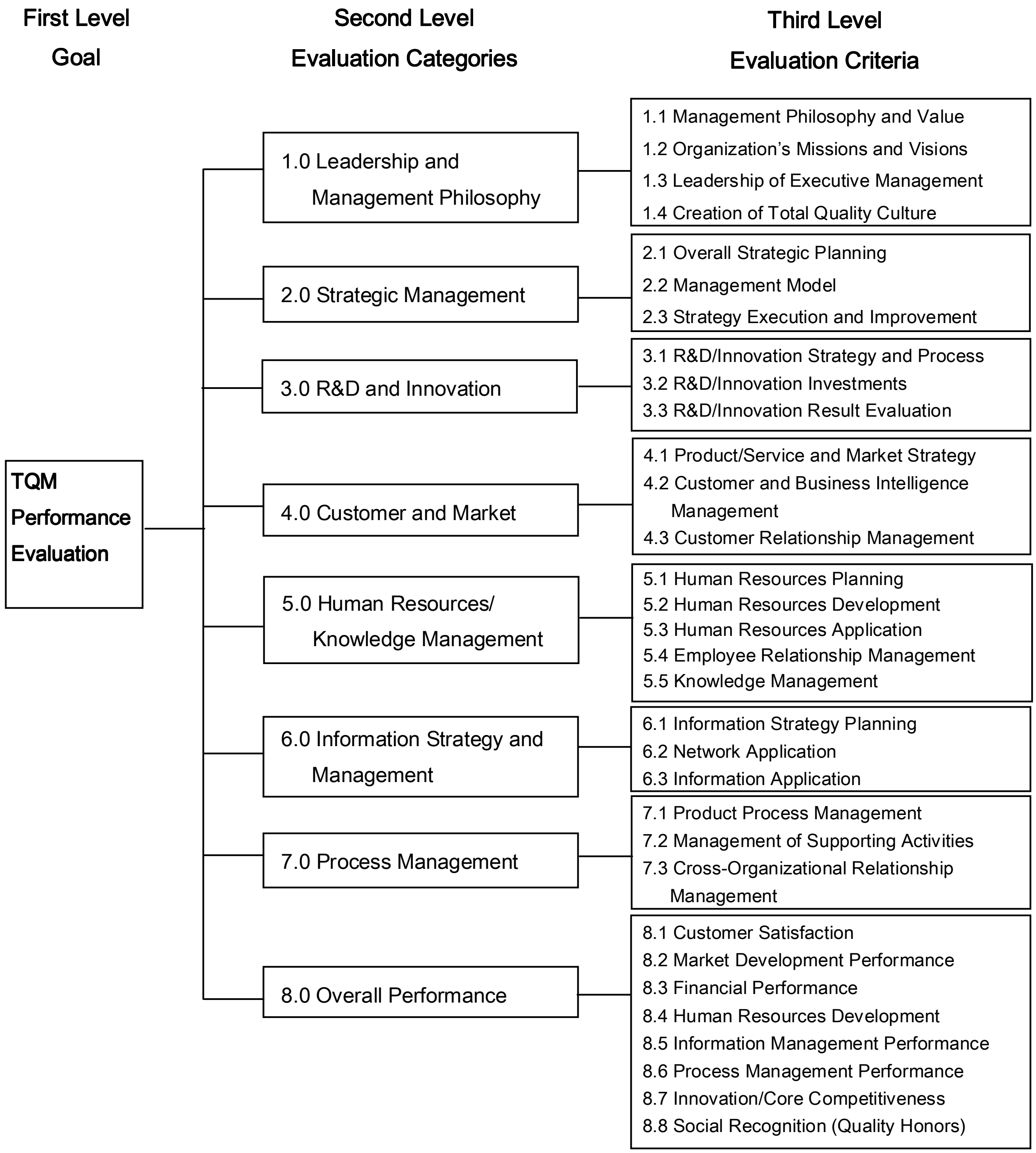

Figure 3. Proposed hierarchical structure of the TQM evaluation based on the TNQA criteria.

standards, profile of interviewed experts, analyses of the calculation of FAHP weights of evaluation criteria by different expert groups, and discussion are further elaborated.

Constructing the hierarchical structure of evaluation standards

The study focuses on examining the evaluation standards for assessing TQM performance of the high-tech industry in Taiwan. Based on the TNQA evaluation standards (including 33 criteria grouped into eight major categories), a hierarchical structure of evaluation model was constructed, and a questionnaire designed to gather experts' opinions on the importance of each standard in the TQM performance of Taiwan's high-tech industry. FAHP is then employed to compute the weight of each standard. The proposed hierarchical structure of the TQM evaluation standards is presented in Figure 3.

Table 3. FAHP weighted values of TNQA categories by industry experts.

First level goal	Second level evaluation categorY	FAHP weight	BNP	STD BNP	Rank
TQM performance evaluation (C.R.=0.031)	1.0 Leadership and management philosophy	(0.094, 0.202, 0.456)	0.251	0.203	2
	2.0 Strategic management	(0.048, 0.112, 0.267)	0.142	0.115	5
	3.0 R&D and innovation	(0.058, 0.045, 0.114)	0.158	0.129	4
	4.0 Customer and market	(0.059, 0.136, 0.324)	0.173	0.140	3
	5.0 Human resources/ knowledge management	(0.021, 0.045, 0.114)	0.060	0.049	8
	6.0 Information strategy and management	(0.024, 0.053, 0.129)	0.069	0.056	6
	7.0 Process management	(0.025, 0.053, 0.127)	0.068	0.055	7
	8.0 Overall performance	(0.115, 0.276, 0.542)	0.311	0.252	1

1 STD BNP = $BNP_i / \sum BNP_i$; and 2. C.R. = 0.031 ≤ 0.1.

Remarks on interviewed experts

As required by FAHP, the interviewees need to be experts in the field or industry under analysis. The research has accordingly solicited opinions from experts specializing in quality management and related fields. The study consulted 15 experts with five from industries, five from government agencies and professional association, and five from the academia. Experts from industries report substantial experiences working in public listed high-tech companies (AU Optronics Corp., UniMicron Corp., and Amkor Technology Taiwan Ltd.). Experts representing the government and professional association are from the Corporate Synergy Development Center (entrusted to host the TNQA), Bureau of Standards, Metrology, and Inspection (BSMI) under Ministry of Economic Affairs (MOEA) (Taiwan's highest authority for product inspection and implementation of quality assurance and certification systems in Taiwan), and Chinese Society for Quality (professional association dedicating to the promotion quality management education and research). Experts from the academia are all professionally trained in the fields of quality, evaluation, and management. Of the 15 participating experts, nine (60%) have worked in the related fields for over ten years and six of them have even been working for more than twenty years. The questionnaire survey was conducted during July and August, 2007. Telephone interviews was initiated first and followed by in-person interviews so as to raise the validity and reliability of the survey results.

Calculating and analyzing weighted values of evaluation criteria

In calculating the weighted values assigned by the experts to the evaluation criteria, the study first separated the FAHP expert questionnaires into three groups, by the three expert types (from industries, government and academia respectively). After separate calculation was completed, all expert questionnaires were collected together for combined calculation. The weight of each evaluation category in the hierarchical structure and that of each evaluation criterion grouped under the category were respectively computed in separate and combined calculations so each category and criterion received four different weights. These different weights were than ranked to check if the experts' different backgrounds exerted any influence on their assigned weights as well as to compare the weights obtained by the study and the weights allocated by TNQA.

Analysis of weighted values by experts from industries

As Table 3 indicates, "8.0 overall performance" emerged as the top evaluation category in the opinions of experts from the high-tech industry, suggesting that performance influences a firm's sustainable development in a significant way since outstanding performance triggers substantial profits that in turn make business expansion possible. Next came "1.0 leadership and management philosophy" that was judged by the industry experts to be the major driving force behind a firm's overall performance. Competent leadership and a solid management philosophy are imperative in charting the right paths of business development and guiding a firm on its way to success. In the third place was "4.0 customer and market development." Industry experts seemed to suggest that a firm's ability to track the latest trends for effective market development and to maintain successful customer relationship help boost up corporate image and business profitability. "3.0 R&D andInnovation" was assigned a weight of 0.129 in the study, obviously higher than the weight it receives in the TNQA model. The growth in weight reflects the relatively greater importance of R&D and innovation in the high-tech industry in which constant technological development and introduc-tion of innovative products make considerable contributions to a firm's sustainable development.

As shown in Table 4, in terms of individual evaluation criteria, industries experts found "1.3 leadership of exe-cutive management" the most important. Good leaders are able to break through obstacles, create new pro-spects, and guide firms to constantly outdo themselves. "1.4 creation of total quality culture" was also regarded as indispensable. Only with a corporate culture dedicating to total quality can a firm develop quality products and services. The responses of industry experts to the questionnaire further revealed the significance of financial and strategic factors. "8.3 overall performance in financial management" was believed to have direct influence on subsequent organizational processes and the implemen-tation of innovation activities. "2.1 overall strategic planning" drafts the blueprint of the entire organizational processes, playing the role of a lighthouse to provide a clear sense of direction so firms will not deviate from their goals.

Analysis of weighted values by experts from government

As Table 5 indicates, "8.0 overall performance" and "1.0 leadership and management philosophy" were identified by experts representing the government respectively as the most and the second most important factors influencing an enterprise's business development. The evaluation category "3.0 R&D and innovation," how-ever, was ranked right after performance and leadership in the third place with a fairly substantial weight of 0.139.

To government experts, R&D and innovation serve as a crucial factor affecting a firm's business perfor-mance. In terms of profit, introducing new-generation products to ensure customer satisfaction is a powerful tool to create maximum business profits.

As shown in Table 6, in terms of individual criteria, three criteria related to R&D and innovation - "3.2 R&D/innovation investment," "3.1 R&D/innovation strategy and process," and "8.7 overall performance in innovation/core competitiveness" – were identified as significant, reflecting clearly the experts' emphasis on the importance of R&D in high-tech industry and explaining why the evaluation category "3.0 R&D and innovation" received a hefty weight. A firm's core competitiveness and its business prospect are crucially related to how the firm plans, monitors, manages, and evaluates its R&D/innovation strategies and processes.

As suggested by the government experts, "3.2 R&D/innovation investment" in particular, serves as a major indictor of "8.3 overall performance in financial manage-ment." Moreover, "7.1 product process management" was also believed to play a key role in a firm's business operation as comprehensive process planning helps reduce cost and reach economies of scale.

Analysis of weighted values by experts from the academia

As Table 7 indicates, "1.0 leadership and management philosophy" was pinpointed by academic experts as the leading factor affecting "8.0 overall performance" with a considerable weight of 0.304, far higher than the weights allocated to other evaluation categories. Indeed, the policies drafted and announced by the executive management, especially those concerning corporate missions and management philosophy, influence every aspect of a firm's operation in a fundamental way; no wonder the weight of leadership came close to rival that of overall business performance.

As shown in Table 8, in terms of individual criteria, four standards grouped under the evaluation category of "1.0 leadership and management philosophy" - "1.3 leader-ship of executive management," "1.4 creation of total quality culture," "1.1 management philosophy and value," and "1.2 organization's missions and visions" – were rated as essential components of a firm's overall business performance. With "1.0 leadership and management philosophy" outranking other evaluation categories and "1.3 leadership of executive management" garnering the highest weight of all evaluation criteria, it is clear that, from the perspective of academic experts, a firm's business success is closely tied to the competence of its executive management and allied leadership factors, including the firm's management philosophy, missions and visions, and the creation of a quality culture with the organization.

Overall analysis of weighted values by all interviewed experts

As summarized in Tables 9 and 10, the results of the experts' opinions synthesized from the three groups (that is, industries, government, and academia) appeared to be similar to those from the separate one. There was, however, one difference to be noted. For academic experts, competent leadership and solid management philosophy were recommended as the most vital loco-motive driving a high-tech firm toward business success and sustainable development. However, results of the

Table 4. FAHP weighted values of TNQA criteria by industry experts.

Evaluation categories/ criteria	Local FAHP weight	Global FAHP weight	BNP	STD BNP	Rank
1.0 Leadership and management philosophy (C.R.=0.044)					
1.1 Management philosophy and value	(0.047, 0.097, 0.296)	(0.004, 0.020, 0.135)	0.053	0.025	17
1.2 Organization's missions and visions	(0.049, 0.129, 0.343)	(0.005, 0.026, 0.156)	0.062	0.029	15
1.3 Leadership of executive management	(0.142, 0.358, 0.845)	(0.013, 0.072, 0.385)	0.157	0.074	1*
1.4 Creation of total quality culture	(0.129, 0.331, 0.776)	(0.012, 0.067, 0.353)	0.144	0.068	2*
1.5 Corporate social responsibility	(0.034, 0.085, 0.233)	(0.003, 0.017, 0.106)	0.042	0.020	20
2.0 Strategic management (C.R.=0.028)					
2.1Overall strategic planning	(0.265, 0.536, 1.125)	(0.013, 0.060, 0.300)	0.124	0.059	4*
2.2 Management model	(0.078, 0.149, 0.309)	(0.004, 0.017, 0.083)	0.034	0.015	25
2.3 Strategy execution and improvement	(0.147, 0.315, 0.605)	(0.007, 0.035, 0.161)	0.068	0.031	14
3.0 R&D and innovation (C.R.=0.066)					
3.1 R&D/innovation strategy and process	(0.204, 0.422, 0.975)	(0.012, 0.052, 0.287)	0.117	0.055	6*
3.2 R&D/innovation investments	(0.132, 0.303, 0.653)	(0.008, 0.037, 0.192)	0.080	0.037	10*
3.3 R&D/innovation result evaluation	(0.122, 0.275, 0.555)	(0.007, 0.034, 0.163)	0.069	0.032	13
4.0 Customer and market (C.R.=0.036)					
4.1 Product/Service and market strategy	(0.146, 0.286, 0.634)	(0.009, 0.039, 0.205)	0.084	0.040	9*
4.2 Customer and business intelligence management	(0.120, 0.238, 0.557)	(0.007, 0.032, 0.180)	0.073	0.034	12
4.3 Customer relationship management	(0.222, 0.476, 0.855)	(0.013, 0.065, 0.277)	0.118	0.056	5*
5.0 Human resources/ knowledge management (C.R.=0.022)					
5.1 Human resources planning	(0.052, 0.104, 0.277)	(0.001, 0.005, 0.032)	0.012	0.006	32
5.2 Human resources development	(0.034, 0.071, 0.182)	(0.001, 0.003, 0.021)	0.008	0.004	33
5.3 Human resources application	(0.083, 0.206, 0.514)	(0.002, 0.009, 0.059)	0.023	0.009	31
5.4 Employee relationship management	(0.107, 0.253, 0.605)	(0.002, 0.011, 0.069)	0.028	0.013	27
5.5 Knowledge management	(0.151, 0.365, 0.766)	(0.003, 0.016, 0.087)	0.036	0.017	23
6.0 Information strategy and management (C.R.=0.064)					
6.1 Information strategy planning	(0.163, 0.357, 0.744)	(0.004, 0.019, 0.096)	0.040	0.019	21
6.2 Network application	(0.102, 0.198, 0.479)	(0.003, 0.010, 0.062)	0.026	0.012	28
6.3 Information application	(0.200, 0.445, 0.927)	(0.005, 0.024, 0.120)	0.049	0.023	19
7.0 Process management (C.R.=0.028)					
7.1 Product process management	(0.225, 0.503, 0.983)	(0.006, 0.027, 0.125)	0.052	0.024	18
7.2 Management of supporting activities	(0.103, 0.196, 0.483)	(0.003, 0.010, 0.061)	0.025	0.011	29
7.3 Cross-Organizational relationship management	(0.140, 0.301, 0.666)	(0.003, 0.016, 0.085)	0.035	0.016	24
8.0 Overall performance (C.R.=0.019)					
8.1 Customer satisfaction	(0.072, 0.182, 0.495)	(0.008, 0.050, 0.268)	0.109	0.051	7*
8.2 Market development performance	(0.028, 0.062, 0.164)	(0.003, 0.017, 0.089)	0.037	0.018	22
8.3 Financial performance	(0.088, 0.233, 0.587)	(0.010, 0.064, 0.318)	0.131	0.062	3*
8.4 Human resources development	(0.017, 0.037, 0.110)	(0.002, 0.010, 0.059)	0.024	0.010	30
8.5 Information management performance	(0.020, 0.049, 0.135)	(0.002, 0.014, 0.073)	0.030	0.014	26
8.6 Process management performance	(0.038, 0.097, 0.242)	(0.004, 0.027, 0.131)	0.054	0.026	16
8.7 Innovation/Core competitiveness	(0.079, 0.200, 0.454)	(0.009, 0.055, 0.246)	0.104	0.049	8*
8.8 Social recognition (quality honors)	(0.052, 0.138, 0.354)	(0.006, 0.038, 0.192)	0.079	0.036	11

1. STD BNP = $BNP_i / \sum BNP_i$; 2. * indicates the top ten important evaluation criteria; and 3. C.R. ≤ 0.1; C.R.H. = 0.032 ≤ 0.1.

Table 5. FAHP weighted values of TNQA categories by government experts.

First level goal	Second level evaluation category	FAHP weight	BNP	STD BNP	Rank
TQM performance evaluation (C.R.=0.054)	1.0 Leadership and management philosophy	(0.071, 0.181, 0.482)	0.245	0.184	2
	2.0 Strategic Management	(0.032, 0.076, 0.241)	0.116	0.087	6
	3.0 R&D and innovation	(0.051, 0.137, 0.368)	0.185	0.139	3
	4.0 Customer and market	(0.037, 0.106, 0.291)	0.145	0.109	4
	5.0 Human resources/ knowledge management	(0.022, 0.050, 0.140)	0.071	0.053	8
	6.0 Information strategy and management	(0.021, 0.053, 0.153)	0.075	0.057	7
	7.0 Process management	(0.034, 0.091, 0.262)	0.129	0.097	5
	8.0 Overall performance	(0.115, 0.307, 0.672)	0.365	0.274	1

1. STD BNP = $BNP_i / \sum BNP_i$; and 2. C.R. = 0.054 ≤ 0.1.

Table 6. FAHP weighted values of TNQA criteria by government experts.

Evaluation category/ Criterion	Local FAHP weight	Global FAHP weight	BNP	STD BNP	Rank
1.0 Leadership and management philosophy (C.R.=0.058)					
1.1 Management philosophy and value	(0.060, 0.125, 0.366)	(0.004, 0.023, 0.176)	0.069	0.029	17
1.2 Organization’s missions and visions	(0.078, 0.193, 0.501)	(0.006, 0.035, 0.241)	0.094	0.038	11
1.3 Leadership of executive management	(0.133, 0.336, 0.770)	(0.009, 0.061, 0.371)	0.147	0.059	3*
1.4 Creation of total quality culture	(0.066, 0.159, 0.387)	(0.005, 0.029, 0.187)	0.073	0.030	16
1.5 Corporate social responsibility	(0.070, 0.188, 0.426)	(0.005, 0.034, 0.205)	0.081	0.033	13
2.0 Strategic management (C.R.=0.028)					
2.1Overall strategic planning	(0.163, 0.329, 0.827)	(0.005, 0.025, 0.199)	0.076	0.031	15
2.2 Management model	(0.074, 0.166, 0.369)	(0.002, 0.013, 0.089)	0.035	0.013	29
2.3 Strategy execution and improvement	(0.202, 0.505, 1.079)	(0.006, 0.038, 0.260)	0.101	0.041	9*
3.0 R&D and innovation (C.R.=0.042)					
3.1 R&D/innovation strategy and process	(0.147, 0.323, 0.736)	(0.007, 0.044, 0.270)	0.107	0.043	7*
3.2 R&D/innovation investments	(0.204, 0.476, 1.056)	(0.010, 0.065, 0.388)	0.155	0.062	1*
3.3 R&D/innovation result evaluation	(0.094, 0.201, 0.456)	(0.005, 0.027, 0.167)	0.067	0.027	19
4.0 Customer and market (C.R.=0.025)					
4.1 Product/Service and market strategy	(0.156, 0.350, 0.847)	(0.006, 0.037, 0.246)	0.096	0.039	10*
4.2 Customer and business intelligence management	(0.104, 0.214, 0.591)	(0.004, 0.023, 0.172)	0.066	0.026	20
4.3 Customer relationship management	(0.166, 0.436, 0.912)	(0.006, 0.046, 0.265)	0.106	0.042	8*
5.0 Human resources/ knowledge management (C.R.=0.037)					
5.1 Human resources planning	(0.043, 0.099, 0.266)	(0.001, 0.005, 0.037)	0.014	0.006	32
5.2 Human resources development	(0.030, 0.062, 0.170)	(0.001, 0.003, 0.024)	0.009	0.004	33
5.3 Human resources application	(0.077, 0.181, 0.443)	(0.002, 0.009, 0.062)	0.024	0.010	30
5.4 Employee relationship management	(0.110, 0.270, 0.649)	(0.002, 0.013, 0.091)	0.036	0.014	28
5.5 Knowledge management	(0.160, 0.389, 0.848)	(0.003, 0.019, 0.119)	0.047	0.018	25
6.0 Information strategy and management (C.R.=0.002)					
6.1 Information strategy planning	(0.188, 0.354, 0.882)	(0.004, 0.019, 0.135)	0.052	0.021	23
6.2 Network application	(0.064, 0.133, 0.291)	(0.001, 0.007, 0.044)	0.018	0.007	31
6.3 Information application	(0.207, 0.514, 1.005)	(0.004, 0.027, 0.153)	0.062	0.025	21

Table 6. Contd.

7.0 Process management (C.R.=0.032)					
7.1 Product process management	(0.234, 0.564, 1.189)	(0.008, 0.051, 0.311)	0.123	0.050	6*
7.2 Management of supporting activities	(0.087, 0.151, 0.428)	(0.003, 0.014, 0.112)	0.043	0.017	26
7.3 Cross-Organizational relationship management	(0.118, 0.285, 0.661)	(0.004, 0.026, 0.173)	0.068	0.028	18
8.0 Overall performance (C.R.=0.031)					
8.1 Customer satisfaction	(0.069, 0.182, 0.470)	(0.008, 0.056, 0.316)	0.127	0.051	5*
8.2 Market development performance	(0.043, 0.116, 0.318)	(0.005, 0.036, 0.214)	0.085	0.034	12
8.3 Financial performance	(0.075, 0.219, 0.571)	(0.009, 0.067, 0.384)	0.153	0.061	2*
8.4 Human resources development	(0.019, 0.046, 0.144)	(0.002, 0.014, 0.097)	0.038	0.015	27
8.5 Information management performance	(0.023, 0.058, 0.184)	(0.003, 0.018, 0.123)	0.048	0.019	24
8.6 Process management performance	(0.029, 0.080, 0.226)	(0.003, 0.024, 0.152)	0.060	0.024	22
8.7 Innovation/Core competitiveness	(0.070, 0.192, 0.498)	(0.008, 0.059, 0.335)	0.134	0.054	4*
8.8 Social recognition (quality honors)	(0.041, 0.108, 0.289)	(0.005, 0.033, 0.194)	0.077	0.032	14

STD BNP = $BNP_i / \sum BNP_i$; * indicates the top ten important evaluation criteria; and C.R. ≤ 0.1; C.R.H. = 0.047 ≤ 0.1.

Table 7. FAHP weighted values of TNQA categories by academic experts.

First level goal	Second level evaluation category	FAHP weight	BNP	STD BNP	Rank
TQM performance evaluation (C.R.=0.047)	1.0 Leadership and management philosophy	(0.132, 0.310, 0.693)	0.378	0.304	1
	2.0 Strategic management	(0.034, 0.072, 0.184)	0.097	0.078	5
	3.0 R&D and innovation	(0.042, 0.100, 0.203)	0.125	0.100	3
	4.0 Customer and market	(0.037, 0.084, 0.324)	0.108	0.087	4
	5.0 Human resources/ knowledge management	(0.028, 0.065, 0.161)	0.085	0.068	6
	6.0 Information strategy and management	(0.026, 0.059, 0.150)	0.078	0.063	8
	7.0 Process management	(0.028, 0.064, 0.158)	0.083	0.067	7
	8.0 Overall performance	(0.108, 0.244, 0.518)	0.290	0.233	2

STD BNP = $BNP_i / \sum BNP_i$; and 2. C.R. = 0.047 ≤ 0.1.

Table 8. FAHP weighted values of TNQA criteria by academic experts.

Evaluation category/ Criterion	Local FAHP weight	Global FAHP weight	BNP	STD BNP	Rank
1.0 Leadership and management philosophy (C.R.=0.062)					
1.1 Management philosophy and value	(0.084, 0.201, 0.482)	(0.011, 0.062, 0.334)	0.136	0.066	3*
1.2 Organization's missions and visions	(0.077, 0.180, 0.433)	(0.010, 0.056, 0.300)	0.122	0.059	5*
1.3 Leadership of executive management	(0.156, 0.334, 0.716)	(0.021, 0.104, 0.496)	0.207	0.101	1*
1.4 Creation of total quality culture	(0.083, 0.216, 0.492)	(0.011, 0.067, 0.341)	0.140	0.068	2*
1.5 Corporate social responsibility	(0.032, 0.069, 0.194)	(0.004, 0.021, 0.134)	0.053	0.030	12
2.0 Strategic management (C.R.=0.049)					
2.1Overall strategic planning	(0.270, 0.450, 0.957)	(0.009, 0.033, 0.176)	0.073	0.035	10*
2.2 Management model	(0.117, 0.240, 0.393)	(0.004, 0.017, 0.072)	0.031	0.015	27
2.3 Strategy execution and improvement	(0.144, 0.310, 0.536)	(0.005, 0.022, 0.099)	0.042	0.024	18
3.0 R&D and innovation (C.R.=0.072)					
3.1 R&D/innovation strategy and process	(0.140, 0.217, 0.419)	(0.006, 0.022, 0.098)	0.041	0.023	19
3.2 R&D/innovation investments	(0.089, 0.152, 0.272)	(0.004, 0.015, 0.063)	0.027	0.014	28
3.3 R&D/innovation result evaluation	(0.348, 0.631, 1.040)	(0.014, 0.063, 0.242)	0.107	0.052	6*

Table 8. Contd.

4.0 Customer and market (C.R.=0.054)					
4.1 Product/Service and market strategy	(0.124, 0.234, 0.569)	(0.003, 0.015, 0.091)	0.036	0.019	23
4.2 Customer and business intelligence management	(0.080, 0.161, 0.345)	(0.002, 0.011, 0.055)	0.022	0.011	31
4.3 Customer relationship management	(0.093, 0.208, 0.410)	(0.003, 0.014, 0.066)	0.026	0.013	29
5.0 Human resources/ knowledge management (C.R.=0.066)					
5.1 Human resources planning	(0.043, 0.099, 0.266)	(0.001, 0.005, 0.037)	0.014	0.006	32
5.2 Human resources development	(0.030, 0.062, 0.170)	(0.001, 0.003, 0.024)	0.009	0.004	33
5.3 Human resources application	(0.077, 0.181, 0.443)	(0.002, 0.009, 0.062)	0.024	0.010	30
5.4 Employee relationship management	(0.110, 0.270, 0.649)	(0.002, 0.013, 0.091)	0.036	0.014	28
5.5 Knowledge management	(0.160, 0.389, 0.848)	(0.003, 0.019, 0.119)	0.047	0.018	25
6.0 Information strategy and management (C.R.=0.001)					
6.1 Information strategy planning	(0.192, 0.314, 0.608)	(0.005, 0.019, 0.091)	0.038	0.021	21
6.2 Network application	(0.200, 0.354, 0.610)	(0.005, 0.021, 0.091)	0.039	0.022	20
6.3 Information application	(0.171, 0.332, 0.558)	(0.005, 0.020, 0.083)	0.035	0.018	24
7.0 Process management (C.R.=0.036)					
7.1 Product process management	(0.245, 0.412, 0.724)	(0.007, 0.027, 0.114)	0.049	0.027	15
7.2 Management of supporting activities	(0.108, 0.168, 0.302)	(0.003, 0.011, 0.048)	0.021	0.010	32
7.3 Cross-Organizational relationship management	(0.232, 0.419, 0.684)	(0.006, 0.027, 0.108)	0.047	0.026	16
8.0 Overall performance (C.R.=0.051)					
8.1 Customer satisfaction	(0.068, 0.150, 0.357)	(0.007, 0.037, 0.185)	0.076	0.037	9*
8.2 Market development performance	(0.042, 0.102, 0.238)	(0.005, 0.025, 0.123)	0.051	0.028	14
8.3 Financial performance	(0.073, 0.174, 0.407)	(0.008, 0.042, 0.211)	0.087	0.042	8*
8.4 Human resources development	(0.028, 0.061, 0.158)	(0.003, 0.015, 0.082)	0.033	0.017	25
8.5 Information management performance	(0.020, 0.042, 0.109)	(0.002, 0.010, 0.056)	0.023	0.012	30
8.6 Process management performance	(0.049, 0.121, 0.276)	(0.005, 0.030, 0.143)	0.059	0.031	11
8.7 Innovation/core competitiveness	(0.115, 0.266, 0.561)	(0.012, 0.065, 0.291)	0.123	0.060	4*
8.8 Social recognition (quality honors)	(0.037, 0.085, 0.201)	(0.004, 0.021, 0.104)	0.043	0.025	17

1. STD BNP = $BNP_i / \sum BNP_i$; 2. * indicates the top ten important evaluation criteria; and 3. C.R. ≤ 0.1; C.R.H. = 0.050 ≤ 0.1.

Table 9. FAHP weighted values of TNQA categories by overall experts.

First level goal	Second level evaluation categories	FAHP weights	BNP	STD BNP	Rank
TQM performance evaluation (C.R.=0.012)	1.0 Leadership and management philosophy	(0.097, 0.228, 0.540)	0.289	0.228	2
	2.0 Strategic management	(0.038, 0.086, 0.231)	0.118	0.093	5
	3.0 R&D and innovation	(0.050, 0.121, 0.296)	0.156	0.123	3
	4.0 Customer and market	(0.044, 0.108, 0.271)	0.141	0.111	4
	5.0 Human resources/ knowledge management	(0.024, 0.053, 0.139)	0.072	0.057	8
	6.0 Information strategy and management	(0.024, 0.056, 0.145)	0.075	0.059	7
	7.0 Process management	(0.029, 0.069, 0.176)	0.091	0.072	6
	8.0 Overall performance	(0.114, 0.279, 0.581)	0.325	0.256	1

1. STD BNP = $BNP_i / \sum BNP_i$; and 2. C.R. = 0.012 ≤ 0.1.

combined calculation gave the credit to "8.0 overall performance." All the interviewed experts agreed that "1.0 Leadership and Management Philosophy" and "3.0 R and D and innovation" are the most fundamental cornerstones upon which a high-tech firm builds its future and pursue ongoing growth in business revenues and sustainable development. A survey on the obtained weights further illustrated that a great majority of the evaluation criteria rated as significant were standards incorporated under the two leading evaluation categories. It is clear that, to survive and excel in the face of rapid industry changes and acute market competition, high-tech firms need to foster competent leadership and management, pursue worthwhile missions and forward-looking visions, create an inspiring corporate culture accentuating quality and innovation, and invest in ongoing research and development.

DISCUSSION

The research adopted Spearman's rank correlation (SPSS10.0) with the purpose to compute the degree of consistency between the ranks while processing ordinal variables. The results of Spearman's rank correlation analysis on the evaluation categories and criteria weighted by the experts are listed in Tables 11 and 12. As indicated by Table 11, ranking of the evaluation categories respectively by all experts and experts from each of the three different sectors (industries, government, and the academia) emerge to be highly correlated (correlation coefficient > 0.8). In terms of the evaluation criteria, results summarized in Table 12 reveal a similar high correlation except for the ranking by academic experts whose correlation with the ranking by industry experts and government experts reads 0.715 and 0.597 respectively. In line with the results of rank correlation analysis, experts from industries, government and the academia are deemed to share a general consensus in their ranking of the evaluation categories and criteria.

The differences between the TNQA categories weighted by the authority and overall experts are summarized in Table 13. Comparison of the TNQA categories weighted by the TNQA authority and overall experts are depicted in Figure 4.

The TNQA authority and overall experts are almost consistent in the weights of the three categories including "2.0 strategic management," "4.0 customer and market development," and "8.0 overall performance" due to all the differences are less than 15%. This reveals that the overall experts agree that for high-tech industry the relative weights of these three categories are similar to the ones assigned by the authority.

In addition, the three categories, "5.0 human resources/ knowledge management," "6.0 information strategy and management," and "7.0 process management," are thought to be less important for the high-tech industry by the interviewed experts since their relative weights synthesized from the overall experts are less than the ones set up by the authority. Especially, "5.0 human resources/ knowledge management" (with a difference of -56.2%), has a large difference more than 50%, indicating that high-tech firms may not pay too much attention on human resource and knowledge management. This may be because that in general the employee backgrounds of high-tech industries are better than those of the other industries. That is, since the employees of high-tech firms are well trained and developed, the efforts made on this field may not take obvious effect.

However, on the contrary, the relative importance of "3.0 R&D and innovation" (with a difference of 36.7%) weighted by the overall experts is found much higher than that assigned by the authority. This demonstrates that increasing investment in R&D activities and involving more in innovation process is an extremely essential movement for high-tech industry especially. And this finding is supported by the previous studies (Davis and Botkin, 1994; Prajogo and Sohal, 2004, 2006). Ac-cording to the comparisons among 17 NQAs by Tan and Lim (2000), there are various emphases in award criteria. The "R&D and innovation" activities that are not addressed in the other NQAs are the focal points in the TNQA standards. It is interesting to contrast the relative weights of the "3.0 R&D and Innovation" category calculated by the study and the one assigned by the authority. For high-tech firms, based on the research finding, R&D and innovation activities seem to have higher priority from the synthesized experts' opinions.

Moreover, "1.0 leadership and management philosophy" (with a difference of 42.5%) is the aspect that needs to be enhanced for high-tech industry as suggested by the overall experts. As discussed earlier, unlike general industries, the environment faced by high-tech firms changes more dynamically and rapidly. For that reason, in response to dramatic changes timely, high-tech firms call for proficient leaderships and managements that are capable of taking a broad and long-term view not only to develop effective strategies (for example, continual investments in R&D) but also to instill innovative corporate culture in whole companies. Among the leading evaluation criteria analyzed previously, as shown in Table 14, the study further finds several evaluation criteria related to "customers" and "R&D and innovation" winning enough recognition from the interviewed experts to get qualified as significant factors affecting a firm's business performance and development. The experts seem to suggest that, in addition to internal R&D and innovation efforts, external customer-related issues should be granted equal attention. A firm needs to keep close track of customer's latest developments, remain responsive to customers' needs, and take those needs into consideration when developing new products or services so as to ensure customer satisfaction. R&D and innovation should further be applied to predict customers' future needs so a firm can constantly satisfy customers' demands to pursue sustainable business development.

In addition, since the present study has shown the significance of R&D and innovation to high-tech industry

Table 10. FAHP weighted values of TNQA criteria by overall experts.

Evaluation categories/ criteria	Local FAHP weights	Global FAHP weights	BNP	STD BNP	Rank
1.0 Leadership and management philosophy (C.R.=0.009)					
1.1 Management philosophy and value	(0.063, 0.139, 0.383)	(0.006, 0.032, 0.207)	0.082	0.037	11
1.2 Organization's missions and visions	(0.068, 0.170, 0.431)	(0.007, 0.039, 0.233)	0.093	0.043	7*
1.3 Leadership of executive management	(0.146, 0.353, 0.794)	(0.014, 0.081, 0.429)	0.175	0.080	1*
1.4 Creation of total quality culture	(0.091, 0.232, 0.542)	(0.009, 0.053, 0.293)	0.118	0.054	4*
1.5 Corporate social responsibility	(0.043, 0.106, 0.274)	(0.004, 0.024, 0.148)	0.059	0.026	19
2.0 Strategic management (C.R.=0.005)					
2.1Overall strategic planning	(0.231, 0.439, 0.979)	(0.009, 0.038, 0.226)	0.091	0.042	8*
2.2 Management model	(0.089, 0.185, 0.362)	(0.003, 0.016, 0.083)	0.034	0.016	25
2.3 Strategy execution and improvement	(0.165, 0.375, 0.717)	(0.006, 0.032, 0.165)	0.068	0.031	14
3.0 R&D and innovation (C.R.=0.004)					
3.1 R&D/Innovation strategy and process	(0.175, 0.338, 0.723)	(0.009, 0.041, 0.214)	0.088	0.040	9*
3.2 R&D/Innovation investments	(0.145, 0.306, 0.618)	(0.007, 0.037, 0.183)	0.076	0.035	12
3.3 R&D/Innovation result evaluation	(0.172, 0.357, 0.691)	(0.009, 0.043, 0.205)	0.086	0.039	10*
4.0 Customer and market (C.R.=0.002)					
4.1 Product/Service and market strategy	(0.136, 0.266, 0.599)	(0.006, 0.029, 0.162)	0.066	0.030	15
4.2 Customer and business intelligence management	(0.127, 0.248, 0.567)	(0.006, 0.027, 0.153)	0.062	0.028	17
4.3 Customer Relationship Management	(0.216, 0.486, 0.923)	(0.009, 0.052, 0.250)	0.103	0.047	6*
5.0 Human resources/ knowledge management (C.R.=0.066)					
5.1 Human resources planning	(0.068, 0.141, 0.365)	(0.002, 0.008, 0.051)	0.020	0.009	32
5.2 Human resources development	(0.045, 0.094, 0.231)	(0.001, 0.005, 0.032)	0.013	0.006	33
5.3 Human resources application	(0.088, 0.208, 0.477)	(0.002, 0.011, 0.066)	0.027	0.011	30
5.4 Employee Relationship Management	(0.113, 0.270, 0.610)	(0.003, 0.014, 0.085)	0.033	0.015	26
5.5 Knowledge Management	(0.121, 0.288, 0.613)	(0.003, 0.015, 0.085)	0.035	0.017	24
6.0 Information strategy and management (C.R.=0.008)					
6.1 Information strategy planning	(0.184, 0.348, 0.753)	(0.004, 0.019, 0.109)	0.044	0.020	23
6.2 Network application	(0.109, 0.211, 0.444)	(0.003, 0.012, 0.064)	0.026	0.010	31
6.3 Information application	(0.198, 0.440, 0.840)	(0.005, 0.025, 0.122)	0.050	0.023	21
7.0 Process management (C.R.=0.004)					
7.1 Product process management	(0.236, 0.494, 0.953)	(0.007, 0.034, 0.168)	0.070	0.032	13
7.2 Management of supporting activities	(0.100, 0.173, 0.400)	(0.003, 0.012, 0.070)	0.028	0.012	29
7.3 Cross-Organizational relationship management	(0.157, 0.333, 0.675)	(0.005, 0.023, 0.119)	0.049	0.022	22
8.0 Overall Performance (C.R.=0.008)					
8.1 Customer satisfaction	(0.071, 0.173, 0.441)	(0.008, 0.048, 0.256)	0.104	0.048	5*
8.2 Market development performance	(0.037, 0.091, 0.234)	(0.004, 0.025, 0.136)	0.055	0.025	20
8.3 Financial performance	(0.079, 0.210, 0.520)	(0.009, 0.058, 0.302)	0.123	0.057	2*
8.4 Human resources development	(0.021, 0.048, 0.137)	(0.002, 0.013, 0.080)	0.031	0.013	28
8.5 Information management performance	(0.021, 0.050, 0.141)	(0.002, 0.014, 0.082)	0.032	0.014	27
8.6 Process management performance	(0.038, 0.099, 0.250)	(0.004, 0.028, 0.145)	0.060	0.027	18
8.7 Innovation/Core competitiveness	(0.087, 0.220, 0.508)	(0.010, 0.061, 0.295)	0.122	0.056	3*
8.8 Social recognition (Quality honors)	(0.043, 0.110, 0.277)	(0.005, 0.031, 0.161)	0.065	0.029	16

STD BNP = $BNP_i / \sum BNP_i$; * indicates the top ten important evaluation criteria; and C.R. ≤ 0.1; C.R.H. = 0.011 ≤ 0.1.

Table 11. Spearman's rank correlation analysis for TNQA categories.

Coefficient	Industry	Government	Academia	Overall
Industry	1.000	0.905**	0.857**	0.952**
Government		1.000	0.857**	0.976**
Academia			1.000	0.905**
Overall				1.000

** $p < 0.01$.

Table 12. Spearman's rank correlation analysis for TNQA criteria.

Coefficient	Industry	Government	Academia	Overall
Industry	1.000	0.831**	0.715**	0.946**
Government		1.000	0.597**	0.876**
Academia			1.000	0.818**
Overall				1.000

** $p < 0.01$.

Table 13. Comparisons of the TNQA categories weighted by the authority and overall experts.

TNQA categories	Weights		Difference* (%)
	TNQA authority	Overall experts	
1.0 Leadership and management philosophy	0.160	0.228	42.5[c]
2.0 Strategic management	0.090	0.093	3.3[a]
3.0 R&D and Innovation	0.090	0.123	36.7[c]
4.0 Customer and market development	0.100	0.111	11.0[a]
5.0 Human resources/knowledge management	0.130	0.057	-56.2[d]
6.0 Information strategy and management	0.090	0.059	-34.4[b]
7.0 Process management	0.090	0.072	-20.0[b]
8.0 Overall performance	0.250	0.256	2.4[a]

Difference = (Overall experts - TNQA Authority)/TNQA Authority; [a] indicates the diffidence < 15%; [b] indicates the diffidence between 15% and 35%; [c] indicates the diffidence between 35%~55%; [d] indicates the diffidence > 55%.

from the TQM perspective, as the innovation measurement model of service industry established by Chuang et al. (2010), the weights of important dimensions in measuring organizational innovation of high-tech industry could be further examined.

CONCLUSIONS AND SUGGESTIONS

Aiming at exploring TQM performance of the high-tech industry in Taiwan, the study adopts the evaluation standards of TNQA that embodies the concepts of TQM, to build up a hierarchical structure of evaluation model and design a questionnaire for collecting opinions from the experienced quality experts across local industries, government, and academia. FAHP is utilized to compute and analyze the relative weight of each criterion. Results of the study are expected to provide reference for high-tech firms to enhance their TQM performance both effectively and efficiently. Conclusions of the study are summarized further.

According to the research results, the evaluation category "8.0 overall performance" is given the highest weighted value in the ranking by experts from industries, experts from government, and all interviewed experts. The weight it receives from the study is even higher than the one assigned to it by TNQA. However, while experts from both industries and government find "business performance" of utmost importance in leading high-tech firms toward sustainable business development, experts from the academia reach a quite different verdict. To academic experts, the executive management as the core of a firm's decision-making is the key directing the firm's business courses and determining its business

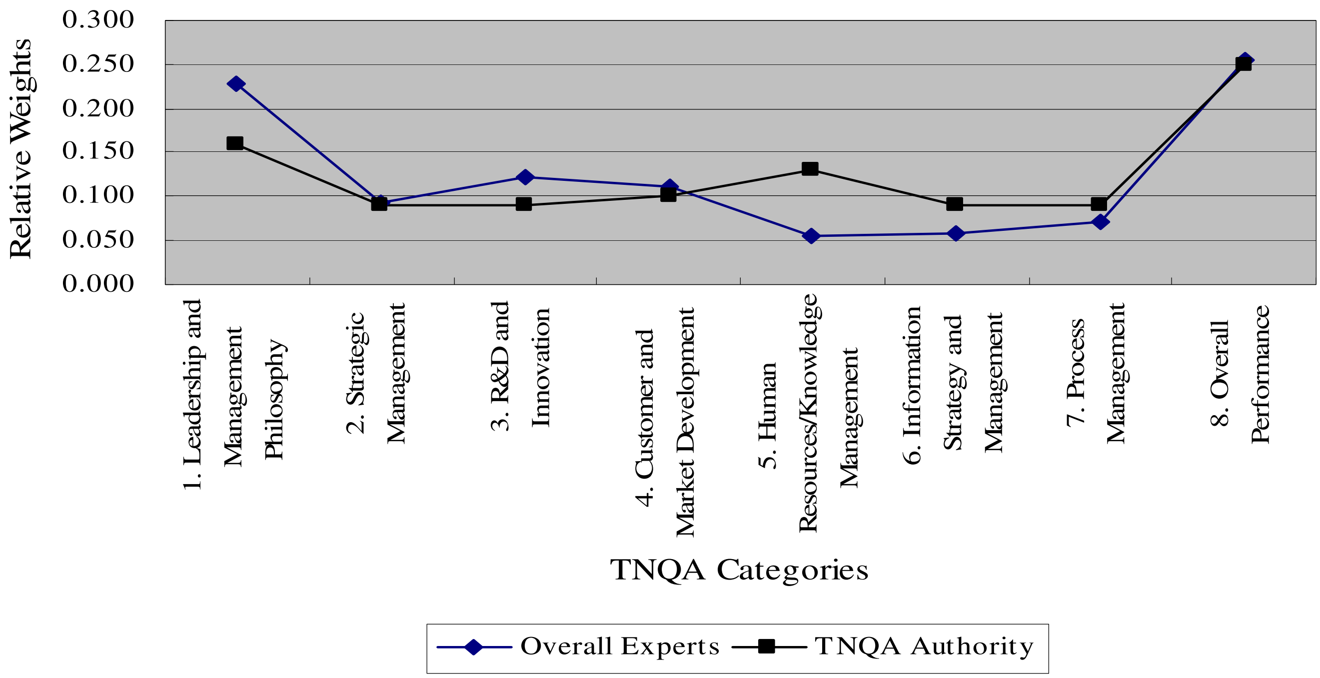

Figure 4. Comparisons of the TNQA categories weighted by the TNQA authority and overall experts.

Table 14. Customer and R&D and Innovation related criteria ranked by the expert groups.

Classification	TNQA criteria	Expert group			
		Industry	Government	Academia	Overall
Customer-related criteria	4.3 Customer relationship management	5*	8*	7*	6*
	8.1 Customer satisfaction	7*	5*	9*	5*
R&D and Innovation-related criteria	3.1 R&D/innovation strategy and process	6*	7*	19	9*
	3.2 R&D/innovation investments	10*	1*	28	12
	3.3 R&D/innovation result evaluation	13	19	6*	10*
	8.7 Innovation/core competitiveness	8*	4*	4*	3*

* indicates the top ten important evaluation criteria by each expert group.

performance. Leadership is a crucial factor influencing the management philosophy of an organization.

In terms of the evaluation categories ranked by all interviewed experts, "8.0 overall performance" and "1.0 leadership and management philosophy" stand on the top with a combined weight approaching 50% of the total weight. In the ranking by experts from the academia alone, combined weight of the two evaluation categories hits 54%, far greater than the combined weight they are allotted in the TNQA model (41%). It is therefore clear that overall business performance is believed to be the best insurance in a high-tech firm's pursuit for sustainable business development while leadership quality and management competence together serve as the key driving force prompting a firm to forge through bottlenecks of profitability to secure maximum business profits.

Compared to the weight it is assigned in the TNQA model (0.09), the evaluation category "3.0 R&D and innovation" is accorded with a greater importance by the experts participating in our questionnaire survey. The weights it receives from industry experts, government experts, and academic experts are 0.129, 0.139, and 0.100 respectively, leading to an average weight of 0.123. It is not surprising to see the evaluation category receiving its greatest weight from industry experts. For the technology-intensive high-tech industry, the results of R&D and innovation are closely tied to business success as they are capable of elevating a firm's competitiveness to a level transcending the mundane competition in the market. As the results of our study demonstrate, the

the weight (0.09) “R&D and innovation” receives in the TNQA model is obviously lower than the one it is assigned by the experts our study have interviewed.

MANAGERIAL IMPLICATIONS

In the face of rapid technological developments and a changing industry environment, enterprises unable to cope with the changes and to adopt appropriate management models in their business operation will soon find themselves marginalized in the market. This is particularly true to high-tech firms who, while endeavoring to outrun their competitors, often have to maintain a certain degree of collaboration with those competitors so as to counter the impacts from the changing industry. High-tech firms therefore need to integrate their internal resources, enhance their R&D and innovation, and develop new-generation products and services so they may rise above the dynamic industry changes to sharpen their competitive edges and to achieve sustainable development.

The eight evaluation categories adopted by TNQA represent the key components and core values of TQM, providing a blueprint for firms striving to pursue sustainable business development through the implementation of a TQM system. However, it should be noted that a firm operates in its individual industry that has its unique features different from other industries. Successful TQM implantation and performance thus require a comprehensive assessment of the host industry’s special features and an in-depth diagnosis of a firm’s particular strengths and weaknesses as the basis to prioritize the key TQM components and to distribute the limited corporate resources in a manner that helps optimize the benefits of the TQM system. Focusing on the high-tech industry, the research interviews domain experts from the industry, government and academia and adopts FAHP to estimate and analyze the weights of the major TQM evaluation categories. It can be expected to offer useful references for high-tech firms in planning optimal resources allocation based on their special needs and enhancing their business performance in terms of the relative importance provided.

Furthermore, on the one hand, the TNQA authority may consult the results of our research to review its current evaluation criteria, assessing the needs to make necessary adjustments in the assigned weights and to examine how the differences between industries may influence the weighting so as to render its evaluation standards more objective and flexible, more capable of guiding various industries to identify priorities for improvement, and more compatible with the optimization of its evaluation performance. On the other hand, the research findings can also provide a valuable reference for the other authorities of the well established NQAs (for example, MBNQA, EFQM, etc.), taking account of adapting the relative weights of evaluation criteria to reflect the spirit of TQM as it is practiced in different industries.

LIMITATIONS AND SUGGESTIONS FOR FUTURE STUDIES

The limitations of the research are summarized as follows. Firstly, the scope of high-tech industry is extremely broad. Based on the research objectives, the research only makes discussions on the overall high-tech industries as a whole; it does not perform in-depth analysis with regard to various domains. Secondly, given that “R&D and innovation,” an independent evaluation standards, is a focus of the research, the TNQA model out of various NQAs is chosen as the hierarchical evaluation structure. Thirdly, in light of the feature of the selected analytical tool (that is, FAHP) the evaluation categories/criteria are assumed to be independent one another. Fourthly, since the research takes high-tech industry as the research object, the relative weights of the evaluation criteria through the synthesized expert questionnaires can provide references mainly for high-tech firms while operating in practice. However, for the high-tech firms that attempt to win the award as a primary end, they are advised to follow the weights drawn up by the authority.

Finally, the suggestions for future studies are outlined further. The research solicits expert opinions on ranking the importance of the TNQA evaluation categories/criteria on high-tech industry and finds the obtained weights inconsistent with those assigned by the TNQA model. Future researchers may direct their focuses on other industries to compare the results with the TNQA allotted weights and to verify if there is a need for the TNQA authority to take the specific features and special needs of different industries into consideration while assigning weights to its evaluation standards. Similarly, further studies may also validate the results by taking other quality-related criteria as evaluation models.

The high-tech industry incorporates a wide spectrum of sub-industries. While our study concentrates on the entire high-tech industry, researchers in the future may like to narrow the scope down to a specific sub-industry for more in-depth study.

Based on the relative weights of evaluation categories/criteria assigned by TNQA and those calculated by the study, further studies may perform empirical analyses (e.g. MCDM) to examine the TQM performance of company practices in high-tech industry and then compare both the similarities and differences in the results to explore further implications. Besides, it is recommended to further investigate the relative importance of detailed dimensions of measuring organizational innovation in the high-tech industry to help improve and enhance R&D and innovation performance.

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