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Full Length Research Paper

Multi-criteria optimization with multiple responses for technological innovation

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This study integrated a multi-criteria response factor design and a multi-criteria optimization method to develop a new model and found the technical innovation multiple responses with multi-criteria optimization design of products and manufacturing processes. This research combined the multiple responses with the multi-criteria optimization design of products and manufacturing processes, and utilized the principle component analysis to compute the principle score of five indicators of innovation ability as dependent variables. Utilizing the factor analysis, the variables were retrenched and the factor scores were computed as independent variables. Furthermore, this research established the response surface models by using principle scores as dependent variables and factor scores as independent variables. Finally, this research analyzed the key influence factors on innovation ability by desirability function and sensitivity analysis. This research proposed the most complete innovation measurement indicators and contributed to the present innovation theory and academic. The results of this research indicated the optimal combination of innovation sources and pointed out that firm supporting, external information sources, evaluation on marketing effect, feasibility study and professional innovation information were the main factors that had a positive impact on innovation performance, while innovation uncertainty was the only factor that had a negative influence on innovation performance in a company. The contribution of this study is seen, more obviously, in the electronic industry. This research enhanced the innovation ability of the industry and analyzed the optimized combination of innovation ability.

Key words: Multi-criteria optimization, response surface model, technological innovation.

INTRODUCTION

Since most innovation studies were done on EU or USA, few of them were done on Asian countries and their topics only discussed the factor’s impact on innovation ability, but none of them proposed which factor and what kind of combination the key factors that influence innovation had. This study establishes an optimization model to resolve the research problem and contribute on industry and academics. Furthermore, this research proposes more complete indicators of innovation measurement. From 1965, when Harrington proposed the concept of optimization, many studies had been conducted in the area. However, they only discussed a single response factor. Intense competition in the global market had forced enterprises to use accurate ways to steer their research, production and operating processes in order to maximize their use of resources. A single response could no longer satisfy their needs. Multiple responses could make up for the insufficiency. An accurate prediction method could not only lower uncertainty, but also provide product innovation information to lower costs, resulting in the maximization of the enterprise’s profit-making ability. This study thus focuses on innovation in products and manufacturing processes in the electronics industry. It investigates the multiple responses of products and the manufacturing processes under the multi-criteria optimization design method.

The aim of this study is to apply the multi-criteria optimization for multiple response product and process design in the manufacturing industry in Taiwan. The results provide companies, operating in Taiwan, with an understanding of how multiple responses of products and manufacturing processes (with the innovation of the multi-criteria optimization design method) can lead to improvement in a company’s process of innovation. Since Taiwan lacks natural resources, it thus forces managers to be more innovative in using human resources more efficiently. To date, initial results in the promotion of innovation have been observed. However, managers have bigger challenges to face in the new century. Being able to contribute to the innovation of knowledge can facilitate an enterprise's continuous success.

This study proposes a multiple response with multi-criteria optimization design of products and the manufacturing process using: (1) the highest revenue-generating products of a company, (2) the highest revenue-generating products in the market, (3) the highest revenue-generating products that are new, (4) maximum productivity and (5) lowest cost. The present study integrates the multi-criteria response factor design and the multi-criteria optimization method to develop a new model and finds the technical innovation of the multiple responses with multi-criteria optimization design of products and manufacturing processes. Independent variables are collected from literature and retrenched by the factor analysis through survey data for predicting the innovation ability. This research combines the multiple responses with the multi-criteria optimization design of products and the manufacturing processes, and it utilizes the principle component analysis to compute the principle score of five indicators of innovation ability as dependent variables. Table 1 displays the impact variables on innovation ability reviewed from previous literature. Utilizing the factor analysis retrenches variables and computes the factor scores as independent variables. Furthermore, this research establishes surface response model by using principle scores as dependent variables and factor scores as independent variables.

Finally, this research analyzes the key influence factors on innovation ability by desirability function and sensitivity analysis. This research proposes the most complete innovation measurement indicators and contributes to the present innovation theory and academic. The contribution of this study is seen, more obviously, in the electronic industry. This research enhances the innovation ability of the industry and analyzes the optimized combination of the innovation ability.

LITERATURE REVIEW

Research studies conducted, using technological innovation as the subjects of analysis, are plentiful. Those that are closely related to the present study, especially those that use similar research data are discussed here. Amara et al. (2005) used data from the 1999 Canadian innovation survey to investigate the question, "what is the effective source of information for the innovation of a manufacturing company?" Four aspects explain how companies could achieve innovation in developing and improving products and processes: internal sources, market sources, research sources and easily-obtained information sources. The two most important results of this study are: (1) companies should use large quantities of information from different sources and (2) companies should use large quantities of information from different research sources to develop and improve products and manufacturing processes.

The results of this study bear significance at the policy level stressing the importance of policies that encouraged cooperation between academia, government and industry. Amara et al. (2005) have focused on the determining factors of product and process innovation in companies especially from external information sources. They have developed a mature theory of innovation based on integration of knowledge and information and have grouped innovations into four categories: (1) innovation created by social networks, (2) innovation based on scientific knowledge, (3) innovation led by market needs, and (4) innovation as a result of technical networking.

Innovation's social resources network

Innovation Social Network Theory stems from two old concepts and a new discovery. The old concept is that innovation is determined by research. In terms of 'technological network theory', knowledge plays an increasingly important role in the innovation of a company. The importance of knowledge has increased day by day and the accumulation of technical knowledge has also continued to increase. The use of communication technology has allowed faster access to knowledge (Cowan et al., 2000). Bartoloni and Baussola (2001) indicate that information technology is extremely important to a company in that it has a positive influence on a company's ability to innovate. This technology not only acts as a pushing hand for innovation in the service industry, but behaves the same way for ordinary industries as well (Hollenstein, 2003). Other researches (Evangelista et al., 1995, 2000; Pavitt, 1987) have indicated that, information-rich service industries often use information technology so extensively, that it can be regarded as the company's indicator of service innovation.

In comparison to the "innovation technological network theory", the "innovation social network theory" places more emphasis on the importance of policy and non-technical tools. Knowledge instead of technical networks becomes the key factor. Innovative development based on knowledge needs technical and relationship tools for its implementation. Technical tools refer to acquisition and use of new information and telecommunications technology. These technical tools do not create a competitive edge because they are easy to obtain and use. The use of relationship tools can create a competitive edge. This is the way to conduct business inside and outside the company. In terms of cooperative networks, Amable et al. (1997) proposes that a knowledge network is a new form of cooperation. It exists in many forms; a technical network is the first form.

Table 1. The definition of independent variable.

Factor	The definition of independent variable	Authors
Generally available information sources used	Trade fairs and exhibitions; Internet or computer based information networks; Professional conferences, meetings and publications	Cohen et al. (1989), Bartoloni et al. (2001)
Internal sources	R&D, Marketing, production, and management staff	Cohen et al. (1989)
Market sources	Suppliers of equipment, material and components, Clients, related firms in your corporate group competitors, Consultancy firms	Von Hippel (1976; 1988), Rothwell (1977), Kline et al. (1986)
Research sources	Federal government agencies and research laboratories University and colleges	Mohnen et al. (2003) Tether (2002)
Government support programs used	Research and development tax credits The sum of the number of the different federal and provincial government programs used by the firms between 1997 and 1999. Government support for training Government venture capital support Government research and development grants Government technology support and assistance programs	Rouvinen (2001), Alice (1990), Bidault et al. (1994), Arvantis et al. (2000), Lundvall (1992, 1995), Nelson (1993), Edquist (1997, 1999), Amable et al. (1997), Niosi (2000)
Competitive environment index	Level of agreement with the following statements (1=Strongly disagree to 5=Strongly agree). Clients can easily substitute their products for the products of their competitors The competitor's actions are easy to predict Clients' demands are easy to predict and the firm can easily replace its current suppliers It is difficult to hire qualified staff and workers It is difficult to retain qualified staff and workers The products quickly become obsolete The arrival of competing products is a constant threat The arrival of competing products is a constant threat Production technologies change rapidly Office technologies change rapidly	Amable et al. (1997; 2005)
Number of employees	Total number of employees	Bartoloni et al. (2001), Rouvinen (2001)
R&D activities	Between 2003 to 2005, the firm undertook R&D	Amable et al. (2005)

Table 1. Contd.

Variety of innovative practices used	The sum of the different innovative practices which are linked to offering new or significantly improved products or to introduce new or significantly improved products and processes Training linked to the introduction of new or significantly improved products or production /manufacturing processes R&D linked to new or significantly improved products or production / manufacturing processes Acquisition of machinery, equipment or other technology linked to new or significantly improved products or production /manufacturing processes The degree of technology intensiveness of the firm The firm operates in a high technology sector	Amable et al. (2005) Cowan et al. (1989; 2000) Bartoloni et al. (2001) Maskell (1999), Amable et al. (2005) Rothwell (1977), Kline et al. (1986) Amable et al. (2005) Cohen et al. (1989), Bruce et al. (1995)
Technology intensiveness	The firm operates in a medium technology sector The firm operates in a low technology sector Between 2004 and 2005, the firms were involved in cooperative and collaborative arrangements with other firms or organization to develop new or significantly improved products	Amable et al. (2005) Rothwell (1977), Cohen et al. (1989),
Collaborative arrangements	Organization with channel of communication can promote cross-departmental communication	
Channels of communication	Division of power and informal organizational structures are conductive to production of innovation, the level of structure of organization	
Power structure	Firms offer sufficient innovation foundation	
Organizational resources	Firm provides psychological resources to support employees enjoy innovation	Wang et al. (2005)
Belief in the importance of innovation	Firms encourage employees' willingness to withstand risk and tolerate mistake and failure; especially employees need to understand the customers' interest.	
Willingness to withstand risk	Employees must express the desire for new knowledge and share innovation	
Power structure	Division of power and informal organizational structures are conductive to production of innovation, the level of structure of organization	

Table 1. Contd.

Organizational resources	Firms offer sufficient innovation foundation	
Belief in the importance of innovation	Firm provides psychological resources to support employees enjoy innovation	
Willingness to withstand risk	Firms encourage employees' willingness to withstand risk and tolerate mistake and failure, especially employees need to understand the customers' interest	Wang et al. (2005)
Willingness to change	Employees must express the desire for new knowledge and share innovation	

From the "innovation technological network theory" to the "social network theory", there are more and more challenges in transferring information to knowledge. Knowledge is used to develop or improve products and processes. Innovation based on knowledge needs not only one, but many kinds of knowledge. In these theories, knowledge is embedded in the industry or in the regional network or in the group of people. In "social network theory", social assets help reduce transfer costs between companies, search and social costs, negotiation and decision-making costs, policy and enforcement costs (Maskell, 1999). Therefore, the hypothesis of the Social Asset Theory, regarding innovation, is that a company has many social assets and competitive advantages. Social assets help to lower the frequency of inappropriate behaviours, increase a sense of honour, and allow employees to share information with each other. The process of globalization increases the distance between employees and reflects the need for companies to cooperate with each other (Maskell, 1999). Social resources take different forms that include basic trust and networking. Trust is the result of constant interaction. The more trusting atmosphere a company can build, the more likely it is to innovate (Knack and Keefer, 1997).

In terms of networking, companies should develop reliable and effective cross-organizational channels of communication. This aspect can be divided into the following six factors:

1. Channels of communication: Internal communication on a regular basis is an important way to disseminate innovative ideas within an organization. It can promote cross-departmental communication (Aiken and Hage, 1971). Moreover, this kind of structure is one way to ensure that the flow of new ideas within an organization never stops (Ross, 1974). The model for organizational knowledge creation proposed by Nonaka advises development of new knowledge through mutual stimulus between individuals. Through interaction, mutual understanding and clear knowledge creation processes, an organization can build a broader and wider knowledge system (Nonaka, 1994).
2. Power structure: According to the research conducted by Subramanian and Nilakanta (1996), division of power and informal organizational structures are more conducive to production of innovation. These researchers propose that the flexibility and openness of these organizational models facilitate the creation of new ideas. Similarly, Kanter (1983) points out that, innovative organizations are "flat" organizations. The flatter the channels of communication, the easier it is to grant power to lower-level workers. On the other hand, concentration of power will constitute a barrier to innovation (Aiken and Hage, 1971; Thompson, 1965).
3. Organizational resources: Organizational stability has been hypothesized to have a positive influence on innovation. It makes an organization purchase innovations, absorb failures, withstand risks of innovation, and consider new ideas before needs appear (Rosner, 1968). The study of Amable et al. (1997) investigated the reasons for the success or failure of innovation and discovered that, the lack of resources will result in innovation failure. Innovation success and abundant innovation capital have a positive correlation.
4. Belief in the importance of innovation: To encourage employees to undertake innovation, a company needs to create a culture of support and reward. Employees need to believe that innovation is worthwhile and that the organization supports

organization supports it. Knight (1986) studied the medium to small enterprises and found three factors related to innovation:

(i) The number of successful cases of innovation.
(ii) The frequency of innovation and its importance is a factor in organizational policy.
(iii) The top officer in organization constantly encourages employees to practice creative thinking. An important factor is psychological and resource support for development of new ideas.

5. Willingness to withstand risk: Innovation often includes uncertainty and risk factors. The more risk a person is willing to withstand; the more innovating performance will be created. Tushman and O'Reilly (1997) pointed out that organizations should encourage its members to accept new ideas and be willing to undertake risky behaviours. They need to be lenient towards mistakes and failures caused by innovation. Employees, especially, need to understand what the customers are interested in.
6. Willingness to change: According to Knight (1986), the research depicted that for innovation to be successful, employees must eagerly express thirst for new knowledge and willingness to express themselves and share.

Innovation networks from market information

The Innovation Engineering Theory states that, external sources of information are decisive innovation factors in the manufacturing industry. More precisely, customers have been used as information sources, to determine manufacturing innovation and product and process improvement, since 1970 (Von Hippel, 1976, 1988; Rothwell, 1977; Kline and Rosenberg, 1986). According to Rothwell (1994), innovation to support the customer or user influences development or improvement of products or manufacturing processes. It accomplishes it in the following ways: (1) By contributing with additional information; (2) Establishing items needed by the user; (3) Contributing sources of information for solutions to new needs; and (4) Increasing the ability to innovate.

The advantage of using customers or users as sources of information for innovations is that, they are in contact with the product for a longer period of time and more frequently. Their suggestions are creative. The innovative products mean innovation for the entire world, not just for a single company. Suppliers can also be one of the information sources for innovation. The information they provide can be used to develop or improve products or processes (Bruce et al., 1995). In addition, the information exchanged between a company and its suppliers is often used for purchasing decisions. In the 1990s, large companies started to lay-off workers and pay attention to their core competitiveness. The role that suppliers played in company innovation also became more important. In the present study, customers, users, and suppliers make up the sources of information from the market. These sources originate development and improvement of products and process innovation.

Innovation engineering based on knowledge

The first theory that uses knowledge as a basis of innovation is the Innovation Engineering Theory. This theory refers to an innovative opportunity to improve products and manufacturing processes. It was discovered as a result of the research. In this theory, the basic research and industrial research and development are the sources of new or major upgrades in products or production processes. These research projects all use linear models to show certain products, patents and publications. In this theory, production is the way to solve this engineering problem. The main problem with this model is that R&D cannot guarantee innovation in products and processes. In reality, innovation can be led by R&D alone but in terms of information source, it can be differentiated into internal and external sources. Despite its limitations, the Linear Innovation Engineering Theory should not be ignored. Internal R&D activities will increase a company's ability to innovate, improve its ability to learn and increase its ability to absorb knowledge from the outside (Cohen and Levinthal, 1989). Internal sources of innovation are important. Research and development activities, the company's human potential and financial resources are the ways in which information and knowledge are brought into a company and through the internal learning knowledge that is accumulated. The research conducted by Bartoloni and Baussola (2001) indicated that, when a company had a highly qualified group of employees, it was easier to introduce new technology.

In terms of assessment of human resources, many studies, Rouvinen (2001) for example, use the proportion of college-educated or the aforementioned college-educated employees in entire staff as indicator. The new finding regarding the influence of R&D activities is that, a company alone cannot conduct innovation (Bidault and Cummings, 1994; Callon, 1992). Therefore, a company should try to increase external sources of information to construct knowledge or to acquire external sources of knowledge through other mechanisms or networks. Innovation networks include customers, suppliers, research partners, large organizations and research institutions.

The technical cooperation R&D network of innovation

In the 1980s, many academic research studies and policy efforts were devoted to investigating strategic alliances, collaborative R&D coalitions and cooperation among competitors (Alics, 1990; Bidault and Cummings, 1994). Three types of motivation for inter-company technical cooperation can be found in the literature: (1) To increase sophistication of new technology, decrease uncertainty in

R&D, and lower R&D costs; (2) To be able to relate to the market; (3) To develop product and process innovation. Innovative development can be divided into two parts. The first part would be obtaining knowledge from suitable partners which facilitate the understanding of pre-organized knowledge (Bidault and Cummings, 1994; Arvantis and Vonortas, 2000), while the second motivation mentioned in the literature is to reduce time from R&D to market (Bidault and Cummings, 1994).

Most research into R&D cooperation discusses the situation in large high tech companies. They try to point out how companies and other institutions conduct R&D collaboratively to raise productivity, but fail to explain how this affects innovation. Towards the end of the 1980s and the mid 1990s, the Innovation Technological Network Theory was expanded to include other sources of information known as "innovation systems" (Lundvall, 1992, 1995; Nelson, 1993; Edquist, 1997; Amable et al., 1997; Edquist and Hommen, 1999; Niosi, 2000). The supporters of theories of this form assume that through technological network cooperation and information exchange, innovative companies can acquire information that is multi-dimensional in nature. These theories stress the importance of external sources of information such as customers, suppliers, consultants, government organizations, national laboratories and university research institutions to companies. These types of theories predict that, a company's continuous and close collaborative R&D with external research institutions will help the company introduce world-class innovative products.

Tether (2002) indicates that, innovation activities are no longer lonely enterprises. Companies need to rely on each other and cooperate. Mohnen and Hoareau (2003) also pointed out that companies would want to collaborate with universities through industry-academia cooperation, in order to acquire the most advanced technology and the results from basic research. In other words, they hope to become partners with universities or other institutions of higher learning to develop advanced technology. Rouvinen (2001) noted that, the three most common partnerships are those between parent-child companies, those with non-academic institutions, and those between universities and non-profit organizations.

Investment of capital in innovation

Cohen and Levinthal (1989) point out that expenditure in innovation is an important variable in assessing whether innovation is successful or not. It is also closely related to a company's decision-making ability when considering new technology and its ability to use new technology to lower risks. However, when estimating the relationship between investment in innovation and production, Peters (2000) discovered that innovation expenditure had a small, but not significant negative influence on new products or implementation of new processes.

THE MULTIPLE RESPONSE WITH MULTI-CRITERIA OPTIMIZATION DESIGN PROBLEM

The problem in multiple response design includes m dependent variables that are influenced by n independent variables. First, there is need to calculate the relationship between the dependent and independent variables. Using the Response Surface Model (Quadratic Polynomial Model), the base model can be expressed as stated in Function (1):

$$y_i = \beta_0 + \beta_{i1}x_1 + \beta_{i2}x_2 + \dots + \beta_{ik}x_k + \beta_{i11}x_1^2 + \beta_{i22}x_2^2 + \dots + \beta_{ik}x_k^2 + \beta_{i12}x_1x_2 + \beta_{i(k-1)k}x_{k-1}x_k + \varepsilon_i \quad (1)$$

i=1,2,…,m where y_i is the score of principle components y_1, y_2, y_3, y_4 and y_5. y_1 refers to revenue from the new product in the market/sales revenue; y_2 refers to revenue gained by the company from the new product/sales revenue; y_3 refers to revenue from the new product/sales revenue; y_4 refers to the proportion of decrease in operating and personnel costs after introduction of the new process; and y_5 refers to the proportion of increase in productivity after introduction of the new process. However, β is the coefficient, while x_i is the explanatory variable. As stated in the literature review, the five aspects making up the independent variables include: innovative engineering based on knowledge, innovative network originating from market information sources, technical R&D cooperation for innovation, social resources network for innovation and investment in innovation. ε_i is the error term; x_ix_J is the explanatory variable for the interaction term; β_1= Coefficients for the linear terms of the i^{th} performance characteristic, l=1,2,…,k; β_{ill} = Coefficients for the squared of the ith performance characteristic, $\beta_{i(K-1)}$ = Coefficients for the interaction term of the i^{th} performance characteristic, ε_i = an error term that is independently distributed with variance of $\sigma_{\varepsilon i}^2$ and mean zero.

DESIRABILITY FUNCTION DESIGN

Desirability function

Transforming each m individual response functions into desirability based on the particular goal for that response is the desirability approach. Individual desirabilities $d_i(\hat{y}_i)$, i=1,2,…,m map response values to unit-less utilities are bounded by 0< $d_i(\hat{y}_i)$<1, where a higher $d_i(\hat{y}_i)$ value indicates that the response value $\hat{y}_i$ is more desirable. Combining the individual desirability values usually involves using either a multiplicative or additive model which results in an overall desirability function associated with the vector of independent variables (x). A common approach is to define the overall desirability as the geometric mean of individual desirabilities where

$$D(x) = \left(d_1(\hat{y}_1) d_2(\hat{y}_2) \ldots d_m(\hat{y}_m)\right)^{1/m} \quad (1)$$

For a target value (two-sided) goal, the individual desirability is seen as in Function (2). Desirability value is between 0 and 1.

$$d = \begin{cases} \left(\dfrac{\hat{y}-L}{T-L}\right)^s & , L \le \hat{y} \le T \ , \quad s \ge 0 \\ \left(\dfrac{U-\hat{y}}{U-T}\right)^t & , T \le \hat{y} \le U, \quad t \ge 0 \\ 0 & , \hat{y} \ge U \quad or\, \hat{y} \le L \end{cases} \quad (2)$$

Where L is the lower limit, U is the upper limit, and T is the target value for response i. The exponents, t and s, are weights that allow for linear (s = t =1) or nonlinear behavior between a bound (L or U) and the target (T).

For the maximization (one-sided) objective, d becomes

$$d = \begin{cases} 0 & , \hat{y} \le L \\ \left(\dfrac{\hat{y}-L}{T-L}\right)^r & , L \le \hat{y} \le T, \quad r \ge 0 \\ 1 & , \hat{y} \ge T \end{cases} \quad (3)$$

Where, L is the lower limit, T is the target value for response i and r is the weighted value.

For the minimization (one-sided) objective, d becomes

$$d = \begin{cases} 1 & , \hat{y} \le T \\ \left(\dfrac{U-\hat{y}}{U-T}\right)^r & , T \le \hat{y} \le U, \quad r \ge 0 \\ 0 & , \hat{y} \ge U \end{cases} \quad (4)$$

where U is the upper limit, T is the target value for response i and r is the weighted value. The exponents, t and s, are weights that allow for linear (s = t =1) or nonlinear behavior between a bound (L or U) and the target (T). Computing the geometric average value of the desirability value of d, the total desirability value, D(x), can be obtained as an innovation measurement indicator as follows.

$$D(\mathrm{x}) = [d_1^{w_1} \cdot d_2^{w_2} \cdot \ldots \cdot d_m^{w_m})]^{1/S} \quad (5)$$

where, w_i , $i = 1,2,\ldots,m$ represents the ith weighted value and $S = \sum_{i=1}^{m} w_i$ (6)

RESEARCH METHODS AND DESIGN

For this research project, industry classification according to the OECD was used and the structure of the country's industries was taken into consideration. This study analyzed the data in the electronics industry. The size of the enterprises was divided according to the number of employees into four categories: 6 to 19, 20 to 49, 50 to 249, and more than 250. These four groups were referred to as extra small enterprises (XSE), small enterprises (SE), medium-sized enterprises (ME) and large enterprises (LE). Internationally, most comparisons and analyses focused on companies with more than 20 employees. This study narrowed the scope of its investigation to companies in the electronics industry, which at the end of the year 2005 employed more than 20 people.

Time and scope of the investigation

Time of investigation was from August 1, 2006 to July 7, 2007. This included selection through phone interviews and face-to-face interviews. The scope of investigation covered companies in the electronics industry in the Taiwan area with more than six employees.

Subjects

Interviewees were employees at the managerial level such as managers, vice-presidents or their delegates.

Main corpus of investigation

The main corpus was derived from the latest data compiled through the "manufacturing, financial and service industries census" by the Executive Yuan.

Sampling method

In the OECD and in the National State of Technology Survey, companies of different industries were divided according to the number of employees. The groups that were selectively surveyed were those which had 6 to 19, 20 to 49, 50 to 249, and 250 to 499 employees. All companies with more than 500 employees were surveyed. Sampling was done using the "manufacturing, financial and service industries census" data as the study population. From that population, random selections were made from each group.

First phase - Phone selection interview: Through a process of phone selection and using a simple survey, companies that have between 6 and 499 employees were asked whether any technical innovation activities took place in the company between 2005 and 2006. The companies that conducted innovation activities became part of the second phase and received a face-to-face interview.

All companies with more than 500 employees became part of the second phase and will receive face-to-face interviews.

Second phase - Face-to-face interview: The companies interview included those which said in the first interview that innovative activities were conducted and companies with more than 500 employees. They received face-to-face interview using the complete survey.

Third phase - Follow-up investigation: To accurately understand the situation of companies that had conducted innovation activities, additional enterprises with 6 to 499 employees were investigated.

In addition, correction for Types I and II errors had been done in the process of sampling so that the estimated value could be more accurate. To correct Type I errors, from the group of companies which answered saying that they did not have innovation activities, a random sample would be selected and face-to-face interviews would be conducted. The proportion of companies that said they had technical innovation and then answered negatively during the face-to-face interview was used to correct Type II errors.

Research procedure

Step 1. Apply principle component analysis to Y for obtaining principle score as a dependent variable. The five variables are as follows: highest revenue-generating products of a company, highest revenue-generating products in the market, highest revenue-generating new products, maximum productivity, and lowest cost.

Step 2. Independent variables are collected from the literature, and retrenched by factor analysis through survey data for predicting innovation ability. The factor scores are retrenched as independent variables by factor analysis.

Step 3. Principle scores as dependent variables and factor scores as independent variables. This research establishes response surface model.

Step 4. Utilizing desirability function determines optimization value and maximizes the principle score.

Step 5. Sensitivity analysis is used to analyze the significant factors to innovation.

RESULTS

Questionnaires were sent to 2000 manufacturing firms in Taiwan with 6 to 499 employees and over 500 employees received them. About 130 usable replies were obtained in this study from May 1st 2007 to June 30th 2007. The principle component analysis was applied to Y for obtainning the principle score as a dependent variable. Utilizing the principle axe factor analysis, this study retrenched 45 variables in 6 factors among 109 questions. Factor loadings higher than 0.5, Eigenvalue more than 2 and Cronbach's α over 0.8 was retrenched by this study as shown in Table 2. Factor 1 has 9 variables and is named feasibility study, factor 2 has 8 variables and is named external information sources, factor 3 has 8 variables and is named firm supporting, factor 4 contained 4 variables and is named innovation uncertainty, factor 5 has 4 variables and is named professional innovation information, factor 6 contained 8 variables and is named evaluation on marketing effect.

Table 3 listed the results of principle component analysis and as such, Factor 1 was named product innovation and Factor 2 as process innovation. Product innovation (Factor 1) contained new product revenue on market/sales revenue (y_1) and the company's new product revenue/sales revenue (y_2). Process innovation (Factor 2) included the decreasing ratio of operating and labor cost (y_3) after adopting a new process, and the increasing ratio of capacity (y_4) after adopting a new process.

Table 4 showed the result of response surface regression, in which most of the variables, square terms and interaction terms significantly influenced product innovation. Few variables were insignificant as Factor 4 (innovation uncertainty), but the square term of Factor 4 had a positive impact on product innovation significantly. F2*F4: (external information sources) *(innovation uncertainty), F2*F5: (external information sources)*(professional innovation information), and F3*F5: (firm supporting)*(professional innovation information) also insignificantly influence product innovation.

Desirability function

Functions (7) and (8) represented the result of the desirability function. Firm support to innovation was the most important factor for innovation, followed by feasibility study, external innovation information, professional innovation information, and evaluation on marketing effect. Innovation uncertainty was negative to innovation.

$$D(\mathrm{x}) = [d_1^{\,w_1} \cdot d_2^{\,w_2} \cdot ... \cdot d_4^{\,w_4})]^{1/4} \quad (7)$$

where, d_1 denotes the combination of sales revenue from innovation; d_2 represents the combination of innovation profit; d_3 is the combination of innovation cost; d_4 displays the combination of innovation efficiency

$$\widehat{D}(\beta) = 0.68851 + 0.01485\beta_1 + 0.00812\beta_2 + 0.02363\beta_3 - 0.00230\beta_4 + 0.00297\beta_5 + 0.00083\beta_6 \quad (R^2 = 0.55) \quad (8$$

β_1 = Factor 1 (feasibility study); β_2 = Factor 2 (external innovation information); β_3 = Factor 3 (firm supporting); β_4 = Factor 4 (innovation uncertainty); β_5 = Factor 5 (professional innovation information); β_6 = Factor 6 (evaluation on marketing effect).

Table 2. Factor analysis.

Variable	Factor loading					
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Q14	0.52					
Q25	0.59					
Q38	0.51					
Q39	0.58					
Q44	0.51					
Q45	0.65					
Q46	0.67					
Q47	0.55					
Q48	0.51					
Q34		0.51				
Q75		0.67				
Q76		0.52				
Q77		0.57				
Q81		0.57				
Q82		0.64				
Q83		0.59				
Q84		0.68				
Q15			0.63			
Q17			0.57			
Q104			0.55			
Q105			0.57			
Q106			0.57			
Q107			0.52			
Q108			0.50			
Q109			0.55			
Q19				0.84		
Q20				0.80		
Q21				0.69		
Q22				0.68		
Q66					0.55	
Q70					0.64	
Q71					0.61	
Q72					0.64	
Q40						0.57
Q41						0.53
Q52						0.59
Q53						0.62
Q54						0.65
Q56						0.68
Q58						0.59
Q59						0.55
Explain variation	7.96	6.07	8.20	3.44	3.92	6.85
Eigenvalue	19.31	5.03	3.78	3.37	2.58	2.37
Cronbach's α	0.88	0.87	0.88	0.89	0.86	0.87

Table 3. The result of principle component analysis for innovation performance.

Variable	Factor loading
Sales revenue from new product	0.64
Market share of innovated product	0.67
Sales growth of innovated product	0.70
Profit from innovated product	0.68
Lower cost from innovated product	0.50
Received period of innovated product	0.62
Stockholders' profits of new service	0.68
Profit margin of new service	0.66
Venture capital of new service	0.42
New customer is attracted by innovated product	0.73
Old customer is retained by innovated product	0.72
Profit from new customer	0.72
New product on the market	0.78
Average product developing cost	0.40
New product input	0.57
Customer loyalty of product improvement	0.70
Enhance firm's image and goodwill	0.64
Efficiency of new product development process	0.62
Complete new product development under the unit cost	0.49
New product development is completed under project budget	0.48
New product development is completed under time limited	0.59
The number of new product is more than that of the competitors	0.53
New product development ratio per year	0.60
Eigenvalue	8.92
Total variance	38.81
Cronbach's α	0.92

$$\hat{D}(RMSE) = 0.84321 + 0.03541(RMSE)_1 + 0.03342(RMSE)_2 + 0.0171(RMSE)_3 - 0.02821(RMSE)_4 - 0.02243(RMSE)_5 + 0.00011(RMSE)_6$$

($R^2 = 0.42$) (9)

When employing the dual response surface method, the computer software, Design-Expert [7], was used to obtain the optimal solution for Equations 30 and 31. The optimal solution was obtained through the Simplex method. The closer c $\hat{D}(\hat{\beta})$ and $\hat{D}(RMSE)$ are to each other, the better they become. Ten out of one hundred possible optimal experimental combina-tions, within the limits of the control factor levels, were selected. These ten optional combinations could simultaneously maximize $\hat{D}(\hat{\beta})$ and $\hat{D}(RMSE)$. Table 3 displays the coded values of these ten optional factor/level combinations. The overall des-irability of each experimental combination was obtained by substituting $\hat{D}(\hat{\beta})$ and $\hat{D}(RMSE)$ into the following equation:

$$OD = (\hat{D}(\hat{\beta}) \times \hat{D}(RMSE))^{\frac{1}{2}} \quad (10)$$

Where: OD represented the overall desirability of each experimental combination. Tables 4 and 5 displayed the OD values for the ten optional factor/level combinations. The aim of the study is to apply the multi-criteria optimization for multiple response product and process design in electronic industries in Taiwan. The result of the Response Surface Regression, and most of the variables, square terms and interaction terms significantly influence product innovation. The optimal combination is group number 115 with the factors shown in Table 6. The results of this research indicated the optimal combination of innovation sources and pointed out that firm suppor-ting, external information sources, evaluation on marke-ting effect, feasibility study, and professional innovation information were the main factors that positively had an impact on innovation performance, while only innovation uncertainty had a negative influence on innovation performance in a company.

Few variables are insignificant as Factor 4 (innovation uncertainty), but the square term of Factor 4 positively had an impact on product innovation significantly. F2*F4:

Table 4. The result of response surface regression.

Independent variables	β	Standard error	Wald Stat.	P-value
Factor 1: Feasibility study	1.77*	0.68	6.75	0.01
Factor 1^2: (Feasibility study) ^{2}	-8.58*	1.22	49.77	0.00
Factor 2: External information sources	3.96*	0.26	239.33	0.00
Factor 2^2: (External information sources) ^{2}	-0.66*	0.12	28.59	0.00
Factor 3: Firm supporting	2.48*	0.39	40.58	0.00
Factor 3^2: (Firm supporting) ^{2}	-6.57*	0.60	120.35	0.00
Factor 4: Innovation uncertainty	0.31	0.43	0.51	0.48
Factor 4^2: (Innovation uncertainty) ^{2}	5.43*	0.69	61.27	0.00
Factor 5: Professional innovation information	-3.61*	0.26	185.05	0.00
Factor 5^2: (Professional innovation information) ^{2}	3.25*	0.35	84.41	0.00
Factor 6: Evaluation on marketing effect	-2.61*	0.58	20.59	0.00
Factor 6^2: (Evaluation on marketing effect) ^{2}	-1.20*	0.36	11.46	0.00
F1*F2: (Feasibility study)* (external information sources)	-0.71*	0.35	4.06	0.04
F1*F3: (Feasibility study)* (firm supporting)	-15.75*	1.02	240.10	0.00
F2*F3: (External information sources) * (firm supporting)	-6.21*	0.47	175.05	0.00
F1*F4: (Feasibility study)* (innovation uncertainty)	5.81*	0.70	68.01	0.00
F2*F4: (External information sources) *(innovation uncertainty)	-1.44	0.86	2.81	0.09
F3*F4: (Firm supporting) *(innovation uncertainty)	8.70*	0.86	102.43	0.00
F1*F5: (Feasibility study)* (professional innovation information)	-1.63*	0.79	4.23	0.04
F2*F5: (External information sources) *(professional innovation information)	-0.38	0.50	0.57	0.45
F3*F5: (Firm supporting) *(professional innovation information)	0.99	0.72	1.85	0.17
F4*F5: (Innovation uncertainty) *(professional innovation information)	3.67*	0.34	115.12	0.00
F1*F6: (Feasibility study)* (evaluation on marketing effect)	2.98*	0.74	16.25	0.00
F2*F6: (External information sources) * (evaluation on marketing effect)	-2.36*	0.27	78.03	0.00
F3*F6: (Firm supporting)* (evaluation on marketing effect)	0.97*	0.44	4.89	0.03
F4*F6: (Innovation uncertainty)* (evaluation on marketing effect)	-7.03*	0.64	121.68	0.00
F5*F6: (Professional innovation information)* (evaluation on marketing effect)	8.32*	0.68	148.35	0.00

Multiple R^2	Adjusted R^2	F-value	P-value
0.49	0.36	3.57*	0.00

(external information sources)*(innovation uncertainty), F2*F5: (external innovation information)*(professional innovation information) and F3*F5: (firm supporting)* (professional innovation information) also insignificantly influence product innovation. The result of desirability function indicates that, firm supporting to innovation is the most important factor for innovation, followed by feasibility study, external innovation information, professional innovation information and evaluation on marketing effect. However, innovation uncertainty is negative to innovation.

The results provide companies operating in Taiwan with an understanding of how multiple responses of products and manufacturing processes with the innovation multi-criteria optimization design method can lead to improvement in a company's process of innovation. Since Taiwan lacks natural resources, hence managers are forced to be more innovative and use human resources more efficiently. To date, initial results in the promotion of innovation have been observed.

However, managers have bigger challenges to face in the new century. Being able to contribute, with the knowledge to innovate, will facilitate an enterprise's continuous success. This study develops a procedure to optimize multiple innovation characteristics in a dynamic system.

CONCLUSION AND SUGGESTION

The merits of the proposed procedure are summarized as follows:

The desirability function can be used to explicitly depict multiple innovation characteristics. The proposed procedure utilizes multiple indicators to determine the optimal factor/level combination. Therefore, conflicts among single

Table 5. The overall desirability of optimal combinations.

Group number	OD	Group number	OD	Group number	OD
1	0.077	44	0.091	87	0.079
2	0.069	45	0.050	88	0.043
3	0.075	46	-0.028	89	0.063
4	0.072	47	0.082	90	0.040
5	0.050	48	0.047	91	0.044
6	0.059	49	0.041	92	0.059
7	0.058	50	0.060	93	0.090
8	0.080	51	0.075	94	0.090
9	0.072	52	0.076	95	0.067
10	0.061	53	0.060	96	0.089
11	0.056	54	0.099	97	0.046
12	0.097	55	0.102	98	0.083
13	0.082	56	0.088	99	0.060
14	0.060	57	0.055	100	0.082
15	0.073	58	0.071	101	0.063
16	0.053	59	0.046	102	0.055
17	0.023	60	0.096	103	0.046
18	0.053	61	0.094	104	0.031
19	0.051	62	0.047	105	0.039
20	0.067	63	0.034	106	0.098
21	0.051	64	0.082	107	0.058
22	0.103	65	0.083	108	0.060
23	0.049	66	0.068	109	0.055
24	0.097	67	0.061	110	0.104
25	0.066	68	0.086	111	0.062
26	0.058	69	0.087	112	0.082
27	0.027	70	0.086	113	-0.013
28	0.056	71	0.058	114	0.119**
29	0.082	72	0.067	115	0.121**
30	0.076	73	0.096	116	-0.011
31	0.050	74	0.069	117	0.082
32	0.054	75	0.104	118	0.089
33	0.045	76	0.048	119	0.080
34	0.097	77	0.084	120	0.075
35	0.086	78	0.074	121	0.078
36	0.070	79	0.084	122	0.026
37	0.095	80	0.074	123	0.074
38	0.114	81	0.078	124	0.042
39	0.071	82	0.110**	125	0.025
40	0.102	83	0.083	126	0.085
41	0.119**	84	0.083	127	0.053
42	0.073	85	0.079		
43	0.036	86	0.107		

among single index for determining the optimal factor/level combinations proposed in the past literature can be avoided. The proposed procedure utilizes regression models and therefore can be employed when the factor levels are continuous.

Finally, the proposed procedure can resolve the multi-response problems in a dynamic system. Management implications of this research should raise attention about innovative company and enhance firm supporting, external information sources, evaluation of the marketing effect, feasibility study and professional innovation information, and should reduce innovation uncertainty.

Table 6. The optimal combination of technological innovation.

Group number	Feasibility study	External information sources	Firm supporting	Innovation uncertainty	Professional innovation information	Evaluation on marketing effect
115	0.66121	1.45603	1.50381	-0.44286	0.46927	1.30277
114	0.18461	1.42541	1.19073	-2.45696	1.21569	1.16620
41	-1.12735	0.14721	2.54708	0.94291	-2.85846	1.26486
82	-2.53618	-2.34175	2.41884	-2.17818	0.95667	-0.99870

This would be the best way to improve innovation performance. Firms should support innovation activities and provide more sources to relative sections to aspire innovation performance.

Participating in professional conferences, reading journal articles, absorbing external information and professional information as much as a firm could, are the best way of transferring external information and professional information into innovation performance. Marketing innovation and performance could reduce transaction costs, thus proving more increased product information to customers. Firms should carefully evaluate marketing performance and integrate more information from customers into innovation activities and then enhance innovation performance. R&D activities, with high uncertainty and therefore how to avoid uncertainty and reduce failure risk are the main issues of every innovative firm. In addition, this research suggested that cooperate and open innovation would be a better way to reduce failure risk.

REFERENCES

Aiken M, Hage J (1971). The organic organization and innovation. Sociol., 5: 63-82.

Alics JA (1990). Cooperation in R&D. Technovation, 10(5): 319-332.

Amable B, Barré R, Boyer R (1997). “Diversity, Coherence and Transformations of Innovation Systems.” In: R Barré, M. Gibbons, Sir John Maddox, B Martin and P Papon (eds) Science in Tomorrow's Europe. Economica International, Paris. pp. 33–49.

Amable B, Demmou L, Ledezma I (2005). Product market regulation, innovation, and distance to frontier. Ind. Corp. Change, 19 (1): 117-159.

Amara N, Rejean L (2005). Souces of information as determinants of novelty of innovatin in manufacturing firms: evidence from the 1999 statistics Canada innovation survey. Technovat., 25: 245-259.

Arvantis R, Vonortas NS (2000), Technology transfer and learning through strategic technical alliances: international experiences: introduction to the symposium. J. Technol. Transfer, 25(1): 9-12.

Bartoloni E, Maurizio B (2001). The determinants of Technology Adoption in Italian Manufacturing Industries. Rev. Ind. Org. 19: 305-328.

Bidault F, Cummings T (1994). Innovating through alliances: expectations and limitations. R&D Manage., 24(1): 33-45.

Bruce M, Leverik F, Litter D, Wilson D (1995). Success factors for collaborative product development: a study of suppliers of information and communication technology. R&D Manage., 25 (1): 33-44.

Callon M (1992). The Dynamics of Technoeconomic Networks. In: Coombs, R., et al., (Eds.), Technical Change and Company Strategies, Academic Press, London.

Cohen WM, Levinthal DA (1989). Innovation and Learning: Two Faces of R&D. Econ. J., 99: 569-596.

Cowan R, David P, Foray D (2000). The explicit economics of knowledge codification and tacitness. Ind. Corp. Change 9(2): 211-254.

Edquist C (1997). Systems of Innovation: Technologies, Institutions, and Organizations. Cassell imprint, London.

Edquist C, Hommen I (1999). Systems of innovation: theory and policy for the demand side. Technol. Soc., 21, 63-79.

Evangelista R, Sirilli G (1995). Measuring Innovation in Services. Res. Eval., 5: 207-215.

Evangelista R (2000). Sectoral Patterns of Technological Change in Services, Economics of Innovation. Econ. Innov. New Technol., 9: 183-221.

Harrington EC (1965). The desirability function, Ind. Qual. Control, 21(10): 494-498.

Hollenstein H (2003). Innovation Modes in the Swiss Service Sector: A Cluster Analysis Based on Firm-level Data. Res. Pol., 32: 845-863.

Kanter RM (1983). The change masters, Simon and Schuster, New York.

Kline SJ, Rosenberg N (1986). An Overview on Innovationm in: R. Landau, N. Rosenberg, The Positive Sum Strategy. National Academy Press, Washington, DC.

Knack S, Keefer P (1997). Does social capital have economic payoff? A cross-country investigation. November. Q. J. Econ., 1251-1288.

Knight R M (1986) Product innovation by smaller, high-technology firms in Canada. J. Prod. Innov. Manage., 3(3):195-203.

Lundvall BA (1992). National systems of innovation.Towards a theory of innovation and interactive learning, Anthem Press, London.

Lundvall BA (1995). The Learning Economy: Some Implications for the Knowledge Base of Health and Education Systems. Knowledge Management in the Learning Society.OECD 2000.

Maskell P, Malmberg A (1999). Localised learning and industrial competitiveness.Camb. J. Econ., 23(2): 167-185.

Mohnen P, Cathy H (2003). What Type of Enterprise Forges Close Links with Universities and Government Labs? Evidence from CIS2. Manag. Decis. Econ., 24(2,3): 133-145.

Nelson RR (1993). National Innovation Systems: AComparative Analysis. Oxford University Press, USA.

Niosi J (2000). Science-based industries: a new Schumpeterian taxonomy. Technology in Society, 22 (4): 429-444.

Nonaka I (1994). A dynamic theory of organizational knowledge creation, Org. Sci., 5: 14-37.

OECD (1995). OECD Proposed Guidelines for Collecting and Interpreting Technological Innovation Data-Olso Manual. Paris: OECD.

Pavitt K, Robson M, Townsend J (1987). The Size Distribution of Innovating Firms in the U.K.:1945-1983. J. Ind. Econ., 35 (3): 297-316.
Peters J (2000). Buyer Market Power and Innovative Activities—Evidence for the German Automobile Industry. Rev. Ind. Org. 16: 13-38.
Rosner MM (1986), Economic determinants of organizational innovation, Admin. Sci. Quart., 12: 614-625.
Ross PF (1974), Innovation adoption by organizations, Pers. Psychol., 27: 21-47.
Rothwell R (1977). The characteristics of successful innovators and technically progressive firms. R&D Manage., 7(3): 191-206.
Rothwell R (1994). Issues in user-producer relations in the innovation process: the role of government. Int. J. Technol. Manage., 9-5-6-7: 629-649.
Rouvinen P (2001). Characteristics of Product and Process Innovators: Some Evidence from the Finnish Innovation Survey. Appl. Econ. Lett. 9: 575-580.
Subramanian A, Nilakanta S (1996). Organizational innovativeness: exploring the relationship between organizational determinants of innovation, types of innovations, and measures of organizational performance. Omega Int. J. Manage. Sci., 24: 631-647.
Tether BS (2002). Who Co-operates for Innovation, and Why—An Empirical Analysis. Res. Pol., 31: 947-967.
Thompson VA (1965). Bureaucracy and innovation. Admin. Sci. Quart., 10: 1-20.
Tushman ML, O'Reilly CA (1997), Winning through innovation, Harvard Business School Press, Boston, MA.
Von Hippel E (1976). The dominant role of the user in the scientific instrument innovation process. Res. Pol., 5(3), 212-239.
Von Hippel E (1988). The Sources of Innovation, Oxford University Press, New York.
Wang D, Chin H Francis L (2005), Determinants of Firm Innovation in Singapore, Technovation, 25: 261-268.

Factor 1: Feasibility study

Q14 denotes the sum of the different innovative practices which are linked to offering new or significantly improved products or to introducing new or significantly improved products
Q25 denotes the sum of the different innovative practices which are linked to offering new or significantly improved processes or to introducing new or significantly improved processes
Q38 denotes training linked to the introduction of new or significantly improved products or production
Q39 denotes training linked to the introduction of new or significantly improved production /manufacturing processes
Q44 denotes R&D linked to new or significantly improved products
Q45 denotes R&D linked to new or significantly improved production / manufacturing processes
Q46 denotes acquisition of machinery, equipment or other technology linked to new or significantly improved products
Q47 denotes acquisition of machinery, equipment or other technology linked to new or significantly improved production /manufacturing processes
Q48 denotes total number of employees

Factor 2: External innovation information

Q34 denotes that innovation information is from trade fairs and exhibitions
Q75 denotes that innovation information is from professional conferences
Q76 denotes that innovation information is from professional magazines
Q77 denotes that innovation information is from suppliers of equipment
Q81 denotes that innovation information is from suppliers of material and components
Q82 denotes that innovation information is from clients
Q83 denotes that innovation information is from related firms in a corporate group's competitors
Q84 denotes that innovation information is from consultancy firms

Factor 3: Firm supporting

Q15 denotes that firms offer sufficient innovation foundation
Q17 denotes that firm provides psychological and resources' support to employees to enjoy innovation
Q104 denotes that firms encourage employees' willingness to withstand risk and tolerate mistake and failure, especially employees need to understand the customers' interest
Q105 denotes that employees must express the desire for new knowledge and share innovation
Q106 denotes that between 2004 and 2005, the firms were involved in cooperative and collaborative arrangements with other firms or organization to develop new or significantly improved products
Q107 denotes that the organization with a channel of communication can promote cross-departmental communication
Q108 denotes that the division of power and informal organizational structures are conducive on the production of innovation, and on the level of the organization's structure
Q109 denotes that between 2003 and 2005, the firm undertook R&D

Factor 4: Innovation uncertainty

Q19 denotes cost factor
Q20 denotes knowledge factor
Q21 denotes market factor
Q22 denotes other factors

Factor 5: Professional innovation information

Q66 denotes that innovation information is from professional publications
Q70 denotes that innovation information is from a professional journal
Q71 denotes that innovation information is from the research laboratories of Universities and colleges
Q72 denotes that innovation information is from government research agencies

Factor 6: Evaluation on marketing effect

Q40 denotes an enhanced marketing proportion
Q41 denotes a developing new market
Q52 denotes an expanding product or service
Q53 denotes extending product lines or increasing service categories
Q54 denotes changing the image of the product or service to customers
Q56 denotes enhancing the customer paying price of product or service
Q58 denotes decreasing the trading cost
Q59 denotes increasing the repurchasing probabilities of customers