Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Technovation 27 (2007) 744–765
technovation
www.elsevier.com/locate/technovation

Reconfiguring the innovation policy portfolios for Taiwan's SIP Mall industry

Chi-Yo Huang[a,*], Joseph Z. Shyu[b], Gwo-Hshiung Tzeng[b,c]

[a]*Department of Industrial Education, National Taiwan Normal University, 162, He-Ping East Road, Section 1, Taipei 106, Taiwan*
[b]*Institute of Management of Technology, National Chiao-Tung University, 1001, Ta-Hsueh Road, Hsin-Chu 300, Taiwan*
[c]*Department of Business Administration, Kainan University, No. 1 Kainan Road, Luchu, Taoyuan 338, Taiwan*

Abstract

Since the year 2000, silicon intellectual property (SIP), which can minimize the gap in 'design productivity' that exists with systems-on-chip (SOC), has become one of the most important factors in the development of integrated circuit (IC) products in the SOC era. Although SIP is very important for IC industry development, complicated business, technical as well as legal issues inside SIP transactions have hindered successful transactions and the integration of SIPs into SOCs. Thus, web-based SIP e-Commerce mechanisms, called SIP Malls, have emerged, aiming to resolve complex SIP issues. To maintain its leading position and competitiveness in the World's IC industry, as well as the value added by SOC products in Taiwanese IC firms, the Taiwanese government has developed SIP Malls, using innovation policy tools. However, the Taiwanese SIP Mall industry remains immature. No existing Taiwanese SIP Malls generate a profit or account for a significant share of worldwide SIP transactions. This research will develop an analytical framework for defining an innovation policy portfolio that aims to develop Taiwan's SIP Mall industry, so that it will enhance the value added of SIP Malls and, thus, the nation's competitiveness in the SIP and IC industries, something which already has become one of the Taiwanese government's major concerns. The industry innovation requirements (IIRs) are summarized using the Delphi method. Meanwhile, the major IIRs identified by Decision Making Trial and Evaluation Laboratory (DEMATEL) are introduced. After the IIRs are derived, the relationships between the IIRs and innovation policy tools are derived by Grey relational analysis (GRA). Then, the innovation policy tools are clustered, based upon the Grey grades derived by GRA. Finally, reconfigured innovation policy portfolios are presented for the Taiwanese government's policy definition. The results demonstrate that developing an innovative policy portfolio that includes scientific, technical, educational, public enterprise, information, legal and regulatory, financial, and taxation policy tools will be the most necessary step towards developing Taiwan's SIP Mall industry.

Keywords: Innovation policy; DEMATEL; Grey relational analysis; Integrated circuit (IC); Systems-on-chip (SOC); Intellectual property (IP); Design and reuse; SIP Mall; Semiconductor

1. Introduction

Capitalism is undergoing an epochal transformation from a mass production system, wherein the principal source of value has been human labor, to a new era of 'innovation-mediated production', wherein the principal component of value creation, productivity and economic growth is knowledge (Florida and Kenney, 1991). Knowledge has become a firm's primary means of generating profits (Bekkers et al., 2002). In knowledge-based industries, knowledge can be marketed to potential partners or clients separate from the products and services that are rooted in the application of specific knowledge (Borg, 2001). A key feature of the commercialization of knowledge is its acquisition and control as 'intellectual property' (IP) (Rappert and Webster, 1997). The production of new knowledge would be optimized by establishing strong IP rights that create incentives for generating knowledge (Adler, 2001).

Knowledge emerges in network relationships between an enterprise and its surrounding organizations, and can be protected legally as IP (Borg, 2001). IP, a legal term describing legally protected intellectual assets in their

---

*Corresponding author. Tel.: +886 936 516698; fax: +886 3 5165185.
E-mail address: georgeh168@gmail.com (C.-Y. Huang).

0166-4972/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.technovation.2007.04.002

various available forms, is the subset of intellectual assets that is legally protected (Sullivan et al., 2002). Patents, trademarks, copyrights, trade secrets, and semiconductor mask works are five major forms of silicon IPs (SIPs) available in the integrated circuit (IC) industry (Sullivan et al., 2002). SIP has existed since the advent of the semiconductor industry. In the early years, IC suppliers—like Fairchild, Intel and Motorola—developed proprietary SIPs for their internal use. During the past decade, IC design productivity has failed to keep pace with Moore's Law, which predicts that the number of electronic devices that can be fabricated on an IC chip will double every 18 months (Moore, 1979). Thus, a 'design gap' between IC design complexity increase and productivity increase has emerged (Semiconductor Industry Association, 2002). IC suppliers began looking for ways to narrow the gap by designing ICs with reusable SIP that tended to contain increasingly complex functionality (Ratford et al., 2003). As IC designs have become more complex, a large number of SIP products are being embedded into the designs. The SIP has become a key segment of the electronic design process, as it can reduce IC development costs, accelerate time-to-market, reduce time-to-volume, and increase end-product value. The nature of SIP, which can narrow the 'design productivity gap', has made SIP critical for the design and implementation of complex systems-on-chips (SOC), which have become the mainstream solution for realization of electronic system products since the year 2000.

Despite the optimistic future that exists for SIP, potential problems, including complex laws and regulations pertaining to SIP transactions, negotiations over SIP usage rights, technical support including SIP integrations into SOCs, maintenance, and SIP application engineering based upon current business models, have emerged as roadblocks to successful SIP business. Apparently, SIP transactions and integrations are not easy. Thus, an e-Commerce mechanism for SIP transactions, the SIP Mall—that aims to provide a well-established SIP database, to increase SIP transaction efficiency, and to provide SOC designers with well-verified reusable SIPs, design environments, and design services—can resolve the above-mentioned business, legal, and technical issues effectively, and be most helpful in accelerating SIP and IC industry growth.

The well-established SIP Malls fill the vacancy that exists in the IC industry structure, resolve existing SIP transaction problems, and enable innovations in IC. The upstream electronic system houses and the fabless IC design houses may develop synergies, by leveraging the SIPs and design services provided by SIP Malls and integrating the manufacturing capacities of IC foundries and assembly houses to roll out innovative SOC products at the most advanced process nodes. Thus, the well-established SIP Malls enhance the nation's competitiveness in the IC industry.

Taiwan is the world's largest semiconductor foundry and second largest fabless IC design provider. To keep the leading position, competitiveness and the value added of Taiwan's foundry, fabless, and thus the IC industry in the SOC era, the Taiwanese government supported the development of Taiwan's SIP Mall industry, by leveraging several policy tools specifically targeting the SOC and SIP industry, including education; research and development (R&D) funding; taxation; and cooperation between R&D institutions, universities and private firms. For example, the Si-Soft project was formed in 2000, followed by the establishment of the Semiconductor Industry Group. Further, with a budget of 7.6 billion NTD, the Ministry of Economic Affairs, Ministry of Education and National Science Council coordinated the first phase of the National Si-Soft Project (Chang and Trappey, 2003) that was aimed at enhancing Taiwan's capabilities in (1) innovative SOC product designs; (2) silicon SIP development; (3) electronic design automation (EDA) flow integration; (4) SIP Malls; and (5) SOC design services, spanning the years from 2002 to 2005. Even though the Taiwanese government has exerted considerable effort into developing the SIP and SIP Mall industries over the past 5 years, Taiwanese SIP Malls still are in the exploratory phase, while SIP sources are limited, and SIP transactions through SIP Malls remain few. How to develop the SIP Mall industry, and how to enhance the value-added nature of SIP Malls, and thus the competitiveness of Taiwan's SIP and IC industries, already have become key concerns of the Taiwanese government.

Therefore, the purpose of this paper is to reconfigure Taiwan's innovation policy portfolios for developing the SIP Mall industry, by analyzing industrial innovation requirements (IIRs) of the SIP Mall industry and proposing innovation policy portfolios based upon the IIRs derived.

Delphic Oracle's Skills of Interpretation and Foresight (Delphi), Decision Making Trial and Evaluation Laboratory (DEMATEL), Grey relational analysis (GRA), and cluster analysis all are used to build an analytical structural framework to derive the innovation requirements for developing Taiwan's SIP Mall industry, reducing the over-complicated IIRs to the most significant IIRs, and then mapping the most significant IIRs to implement the innovation policy tools being proposed by Rothwell and Zegveld (1982). From these analytical results, the authors found that scientific and technical as well as education tools are the most important policy tools, while public enterprise, information, financial, taxation, and legal and regulatory tools also will be necessary to develop Taiwan's SIP Mall industry.

The remainder of this paper is organized as follows. In Section 2, the concepts of innovation and innovation policy are introduced. In Section 3, an analytical framework and methods are proposed for constructing the IIRs and innovation policy portfolio definitions. These include first collecting IIRs by Delphi, then deriving major IIRs by DEMATEL, and concluding with the key innovation policies developed by analyzing the relationships between IIRs and innovation policies using GRA. Finally, the innovation policy tools are clustered as portfolios using cluster analysis. The background of SIP Mall industry development will be described in Section 4. Then, in Section 5, an empirical study follows, reconfiguring the innovation policy portfolios for developing Taiwan's SIP Mall industry. Discussions will be presented in Section 6. Section 7 will conclude the whole article with observations, conclusions and recommendations for further study.

2. Concepts of innovation, industrial innovation requirements and innovation policy

Researchers have successfully explored the definitions of innovation, innovation theories, the rationale of government interventions on innovation, innovation policy instruments, and the relationships between new technologies, emerging markets, innovative services, and economic growth. In the following section, the related literature is reviewed.

Innovation is combinations of knowledge that result in new products, processes, input and output markets, or organizations (Sundbo, 2003) which include not only technical innovations, but also organizational and managerial innovations, new markets, new sources of supply, financial innovations, and new combinations (Perlman and Heertje, 1991). Innovation is a critical factor in enhancing a nation's competitiveness. National governments have pursued planning in innovation policies to improve their nation's growth. In a knowledge-based economy, innovation through the creation, diffusion and use of knowledge has become a key driver of economic growth (Carayannis et al., 2006).

Industrial innovation includes technical design, manufacturing, management and commercial activities involved in the marketing of a new (or improved) product or the first commercial use of a new (or improved) process or equipment (Freeman, 1982). The factors required for industrial innovation or IIRs include technical knowledge, manpower, market information, management skills, financial resources, R&D environments, a domestic market, and an international market (Fig. 1) (Rothwell and Zegveld, 1982). Industrial innovation, indeed, can increase overall economic development (Rothwell and Zegveld, 1982).

Most economic functions in a modern society are best fulfilled by the market mechanism and capitalist firms. However, sometimes there are reasons to complement—or correct—the market and its capitalist actors through public intervention, in such areas as law, education, environment, infrastructure, research, social security, and income distribution. In some of these fields, there is no market mechanism at all, and the functions are fulfilled through use of other mechanisms, like regulation (Edquist, 2001).

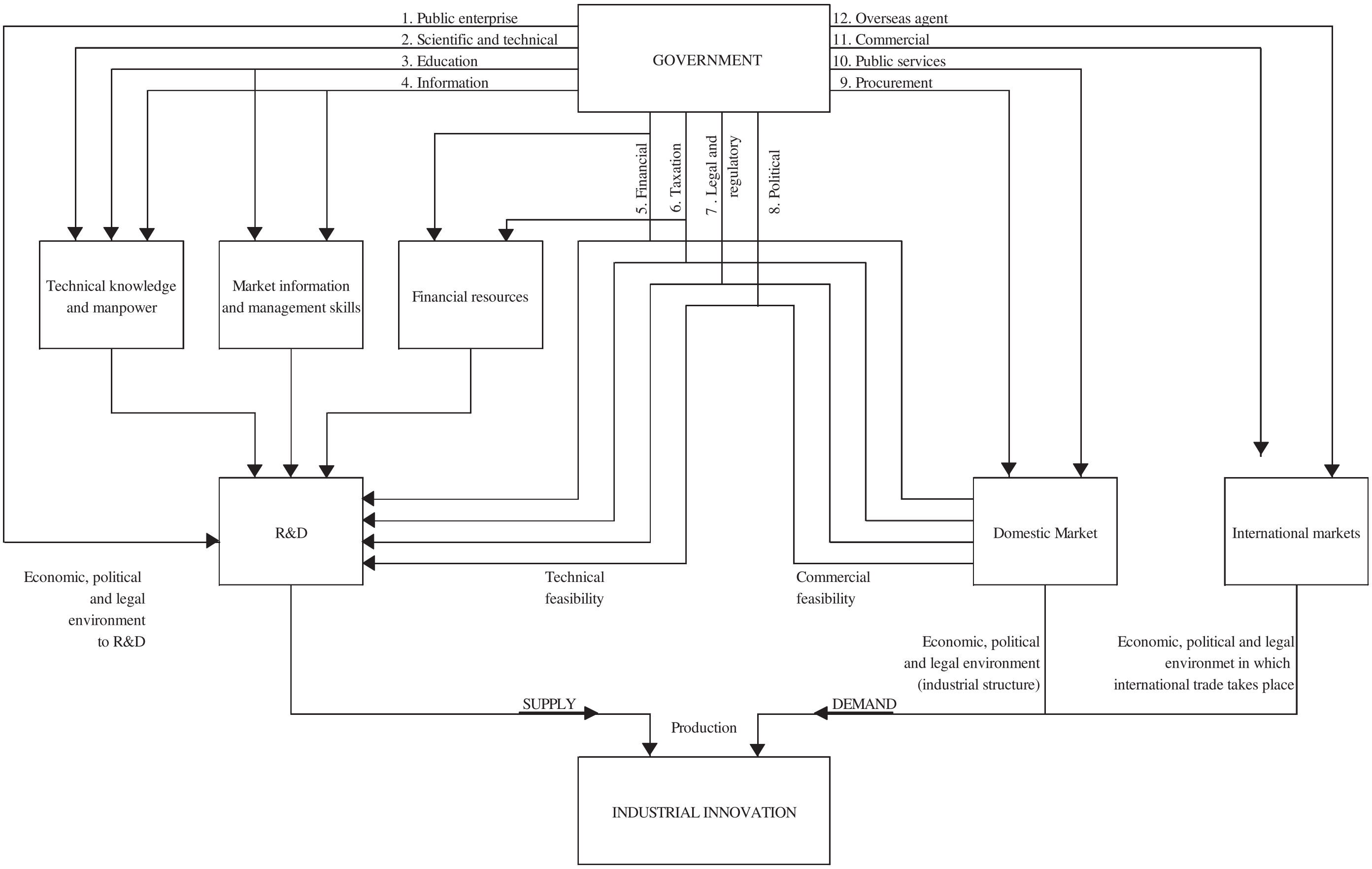

Fig. 1. Possible policy targets and tools that induce innovation.

Thus, government intervention may be needed at certain specific stages of the innovation process. For centuries, governments have pursued policies to improve the innovative performance of domestic industries, and to enhance the economic returns to these domestic firms and their citizens from indigenously developed technologies (Mowery, 1995). The role of government in innovation is not monolithic. From supporting basic research to building infrastructures and establishing regulations, government policy-makers can define industries and affect the fortunes of individual firms (Hung and Chu, 2006). Meanwhile, governments exert a strong influence on the innovation process, via the financing and steering of public organizations that are directly involved in knowledge generation and diffusion (like universities and public labs), and through the provision of financial and regulatory incentives (Carayannis et al., 2006). Taiwan's Hsin-Chu science-based industrial park and Bangalore's software cluster in India (Wonglimpiyarat, 2006) are typical examples of the success of governmental interventions in innovation. To summarize, a national government may want to play a role in the process of innovation, because of: (1) the 'public' nature of the knowledge that underpins innovation; (2) the uncertainty that often plagues the process of innovation; (3) the need for certain kinds of complementary assets; (4) the nature of certain technologies; and (5) plain politics (Afuah, 1998).

Edquist and Hommen (1999) defined science, technology, and innovation policy (in the narrow sense) as specific parts of what could be labeled more broadly as 'innovation policy.' Science policy is the most supply-side-oriented of the policies, and the least direct. Technology policy is the most difficult to define, because technological research varies significantly within the continuum, from relatively mono-disciplinary scientific research to multidisciplinary commercial innovation. However, innovation policy that is oriented toward appropriate new product ideas, production processes, and marketing concepts can produce competitive advantages (Edquist and Hommen, 1999).

The search for appropriate policy tools is not easy. Macro measures are not effective; thus, proposals like a general R&D tax credit are pointless. Policies must be designed to influence particular economic sectors and activities. In this regard, the key policy problem is to augment or redesign institutions, rather than to achieve particular resource allocations (Shyu, 1999). Government intervention can be in the form of financing R&D; acting as a lead user; providing complementary assets; regulating a firm's activities; educating the workforce; maintaining macroeconomic fundamentals; and maintaining political stability in order to attract investment in the innovation (Afuah, 1998). A list of possible innovation policies provided by Rothwell and Zegveld (1982) is categorized into 12 groups and summarized in Table 1. These groups represent the policies that affect the innovation environment and the technological systems. The aims and governmental expectations of public policies towards innovation are many and varied, as are the policies themselves and the tools designed to meet policy aims. Innovation policy tools generally can be grouped under three main categories: (1) *Supply*: provision of financial, manpower and technical assistance, including the establishment of a scientific and technological infrastructure; (2) *Demand*: central and local

Table 1
Classification of government policy tools

Policy tool	Examples
Supply side	
Public enterprise	Innovation by publicity owned industries, setting up of new industries, pioneering use of new techniques by public corporations, participation in private enterprise
Scientific and technical	Research laboratories, support for research association, learned societies, professional associations, research grants
Education	General education, universities, technical education, apprenticeship schemes, continuing and further education, retraining
Information	Information networks and centers, libraries, advisory and consultancy services, databases, liaison services
Environmental side	
Financial	Grant loans subsidies, financial sharing arrangements, provision of equipment, buildings or services, loan guarantees, export credits
Taxation	Company, personal, indirect and payroll taxation, tax allowances
Legal and regulatory	Patents, environmental and health regulation. inspectorates, monopoly regulations
Political	Planning, regional policies, honor or awards for innovation, encouragement of mergers of joint consortia. public consultation
Demand side	
Procurement	Central or local government purchases and contracts, public corporations R&D contracts, prototype purchases
Public services	Purchases, maintenance, supervision and innovation in health service, public building, construction, transport, telecommunications
Commercial	Trade agreements, tariffs, currency regulations
Overseas agent	Defense sales organizations

Source: Rothwell and Zegveld (1982, p. 61).

government purchases and contracts, notably for innovative products, processes and services; and (3) *Environment*: taxation policy, patent policy and regulations (e.g. economic, worker health and safety, and environment) that comprise those measures that establish the legal and fiscal framework in which industry operates.

As stated by Salmenkaita and Salo (2002), there are no straightforward answers to the questions: what elements should an innovation policy include, and how should such policies be implemented? Thus, the current authors have chosen to focus on this topic, so as to define a quantitative innovation policy portfolio definition procedure, and then verified this procedure by analyzing the SIP Mall industry, using a case study from Taiwan's SIP Mall industry.

3. Analytical framework and methods for innovation policy portfolio definition

The analytical framework for defining innovation policy portfolios is initiated by collecting the IIRs needed to develop a nation's SIP Mall industry, using the Delphi method. Since any IIRs derived by Delphi may impact one another, major IIRs were identified using DEMATEL. Finally, GRA was applied to determine the correlation between the major IIRs and the innovation policy tools. Based upon the GRA results, the innovation policy portfolio was derived. In summary, this evaluation framework (Fig. 2) consists of four main phases: (1) establishing IIRs using the Delphi method; (2) simplifying the IIRs using DEMATEL; (3) correlating the IIRs and policy tools and, thus, ranking the priorities of the innovation policy tools with GRA; and finally, (4) deciding the innovation policy portfolios, by means of cluster analysis.

3.1. Delphi method

The Delphi method originated in a series of studies conducted by the RAND Corporation in the 1950s (Jones and Hunter, 1995). The objective was to develop a technique to obtain the most reliable consensus from a group of experts (Dalkey and Helmer, 1963). While researchers have developed variations of the method since its introduction, Linstone and Turoff (1975) captured its common characteristics in the following description: Delphi may be characterized as a method for structuring a group communication process; so the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem. To accomplish this 'structured communication,' certain aspects should be provided: some feedback of individual contributions of information and knowledge; some assessment of the group judgment or viewpoint; some opportunity for individuals to revise their views; and some degree of anonymity for individual responses (Linstone and Turoff, 1975). The Delphi technique enables a large group of experts to be surveyed cheaply, usually by mail using a self-administered questionnaire (although computer communications also have been used), with few geographical limitations on the sample. Specific situations have included a round in which the participants meet to discuss the process and resolve any uncertainties or ambiguities in the wording of the questionnaire (Jones and Hunter, 1995). The Delphi method proceeds in a series of communication rounds, as follows:

> Round 1: Either the relevant individuals are invited to provide opinions on a specific matter, based upon their knowledge and experience, or the team undertaking the Delphi expresses opinions on a specific matter and selects suitable experts to participate in subsequent questionnaire rounds; these opinions are grouped together under a limited number of headings, and statements are drafted for circulation to all participants through a questionnaire (Jones and Hunter, 1995).
> Round 2: Participants rank their agreement with each statement in the questionnaire; the rankings then are summarized and included in a repeat version of the questionnaire (Jones and Hunter, 1995).
> Round 3: Participants re-rank their agreement with each statement in the questionnaire, and have the opportunity to change their score, in view of the group's response; the re-rankings are summarized and assessed for their degree of consensus: if an acceptable degree of consensus is obtained, the process may cease, with the final results then fed back to the participants; if not, this third round is repeated (Jones and Hunter, 1995).

3.2. DEMATEL method

The DEMATEL method was developed by the Battelle Geneva Institute: (1) to analyze complex 'world problems' dealing mainly with interactive man-model techniques; and

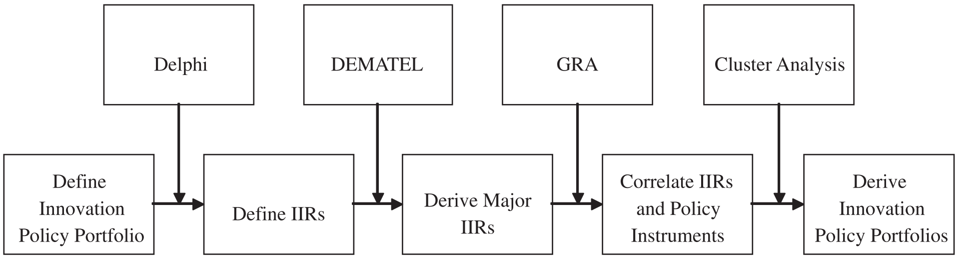

Fig. 2. The analytic framework for an innovation policy portfolio definition.

(2) to evaluate qualitative and factor-linked aspects of societal problems (Gabus and Fontela, 1972). The applicability of the method is widespread, ranging from industrial planning and decision-making to urban planning and design, regional environmental assessment, analysis of world problems, and so forth. To apply the DEMATEL method smoothly, the authors refined the definitions by Hori and Shimizu (1999) and Chiu et al. (2006), and produced the essential definitions indicated below.

The DEMATEL method is based upon graph theory, enabling us to plan and solve problems visually, so that we may divide multiple criteria into a cause and effect group, in order to better understand causal relationships. Directed graphs (also called digraphs) are more useful than directionless graphs, because digraphs will demonstrate the directed relationships of sub-systems. A digraph typically represents a communication network, or a domination relationship between individuals, etc. Suppose a system contains a set of elements, $S = \{s_1, s_2, \ldots, s_n\}$, and particular pair-wise relationships are determined for modeling, with respect to a mathematical relationship, MR. Next, portray the relationship MR as a direct-relation matrix that is indexed equally in both dimensions by elements from the set S. Then, extract the case for which the number 0 appears in the cell (i, j), if the entry is a positive integral that has the meaning of:

- the ordered pair (s_i, s_j) is in the relationship MR;
- it has the kind of relationship regarding that element such that s_i causes element s_j.

The digraph portrays a contextual relationship between the elements of the system, in which a numeral represents the strength of influence (Fig. 3). The elements s_1, s_2, s_3 and s_4 represent the factors that have relationships in Fig. 9. The number between factors is influence or influenced degree. For example, an arrow from s_1 to s_2 represents the fact that s_1 influences s_2 and its influenced degree is two. The DEMATEL method can convert the relationship between the causes and effects of criteria into an intelligible structural model of the system (Chiu et al., 2006).

Definition 1. The pair-wise comparison scale may be designated as 11 levels, where the scores 0, 1, 2, …, 10 represent the range from 'no influence' to 'very high influence.'

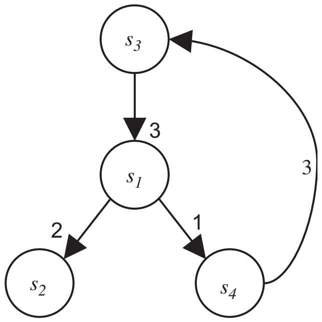

Fig. 3. The directed graph.

Definition 2. The initial direct relation/influence matrix $\boldsymbol{A}$ is an $n \times n$ matrix obtained by pair-wise comparisons, in terms of influences and directions between the IIRs, in which a_{ij} is denoted as the degree to which the ith IIR affects the jth IIR.

$$\boldsymbol{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}.$$

Definition 3. The normalized direct relation/influence matrix $\boldsymbol{N}$ can be obtained through Eqs. (1) and (2), in which all principal diagonal elements are equal to zero.

$$\boldsymbol{N} = z\boldsymbol{A}, \tag{1}$$

where

$$z = 1 \Big/ \max_{1 \leqslant i \leqslant n} \sum_{j=1}^{n} a_{ij}. \tag{2}$$

In this case, $\boldsymbol{N}$ is called the normalized matrix. Since

$$\lim_{k \to \infty} \boldsymbol{N}^k = [0].$$

Definition 4. Then, the total relationship matrix $\boldsymbol{T}$ can be obtained using Eq. (3), where $\boldsymbol{I}$ stands for the identity matrix.

$$\mathrm{T} = \boldsymbol{N} + \boldsymbol{N}^2 + \ldots + \boldsymbol{N}^k = \boldsymbol{N}(\boldsymbol{I} - \boldsymbol{N})^{-1}, \tag{3}$$

where $k \to \infty$ and $\boldsymbol{T}$ is a total influence-related matrix; $\boldsymbol{N}$ is a direct influence matrix and $\boldsymbol{N} = [x_{ij}]_{n \times n}$; $\lim_{k \to \infty} (\boldsymbol{N}^2 + \cdots + \boldsymbol{N}^k)$ stands for a indirect influence matrix and $0 \leqslant x_{ij} < 1$. So, $\lim_{k \to \infty} \boldsymbol{N}^k = [0]$. Detailed calculation procedures are illustrated in Appendix A.

The (i, j) element t_{ij} of matrix $\boldsymbol{T}$ denotes the direct and indirect influences of factor i on factor j.

Definition 5. The row and column sums are separately denoted as $\boldsymbol{r}$ and $\boldsymbol{c}$ within the total-relation matrix $\boldsymbol{T}$ through Eqs. (4)–(6).

$$\boldsymbol{T} = [t_{ij}], \quad i,j \in \{1, 2, \ldots, n\}, \tag{4}$$

$$\boldsymbol{r} = [r_i]_{n \times 1} = \left[\sum_{j=1}^{n} t_{ij} \right]_{n \times 1}, \tag{5}$$

$$\boldsymbol{c} = [c_j]_{1 \times n} = \left[\sum_{i=1}^{n} t_{ij} \right]_{1 \times n}, \tag{6}$$

where the $\boldsymbol{r}$ and $\boldsymbol{c}$ vectors denote the sums of the rows and columns, respectively.

Definition 6. Suppose r_i denotes the row sum of the ith row of matrix $\boldsymbol{T}$. Then, r_i is the sum of the influences dispatching from factor i to the other factors, both directly and indirectly. Suppose that c_j denotes the column sum of the jth column of matrix $\boldsymbol{T}$. Then, c_j is the sum of the influences that factor i is receiving from the other factors. Furthermore, when $i=j$ (i.e., the sum of the row sum and the column sum (r_i+c_j) represents the index representing the strength of the influence, both dispatching and receiving), (r_i+c_j) is the degree of the central role that factor i plays in the problem. If $(r_i–c_j)$ is positive, then factor i primarily is dispatching influence upon the other factors; and if $(r_i–c_j)$ is negative, then factor i primarily is receiving influence from other factors (Tamura et al., 2002).

3.3. GRA method

Since Deng (1982) proposed Grey theory, related models have been developed and applied to MCDM problems. Similar to fuzzy set theory, Grey theory is a feasible mathematical means that can be used to deal with systems analysis characterized by inadequate information. Fields covered by the Grey theory include systems analysis, data processing, modeling, prediction, decision-making, and control engineering (Deng, 1985, 1988, 1989; Tzeng and Tasur, 1994). In this section, we briefly review some relevant definitions and the calculation process for the Grey Relation Model. This research modified the definitions by Chiou and Tzeng (2001) and produced the definitions indicated below.

GRA is used to determine the relationship between two sequences of stochastic data in a Grey system. The procedure bears some similarity to pattern recognition technology. One sequence of data is called the 'reference pattern' or 'reference sequence,' and the correlation between the other sequence and the reference sequence is to be identified (Deng, 1986; Tzeng and Tasur, 1994; Mon et al., 1995; Wu et al., 1996).

Definition 7. The relationship scale also may be designated into 11 levels, where the scores 0, 1, 2, …, 10 represent the range from 'no relationship' to 'very high relationship' between the specified IIR and the innovation policy.

Definition 8. The initial relationship matrix $\boldsymbol{G}$ is an $m\times n$ matrix, where there are m innovation policy tools and n IIRs, obtained by surveying the relationships, where g_{ki} is denoted as the relationship between the kth IIR and the ith innovation policy tool.

$$\boldsymbol{G}=\begin{bmatrix} g_{11} & \cdots & g_{1i} & \cdots & g_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ g_{k1} & \cdots & g_{ki} & \cdots & g_{kn} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ g_{m1} & \cdots & g_{mi} & \cdots & g_{mn} \end{bmatrix}.$$

Definition 9. The normalized relationship matrix $\boldsymbol{G}$ can be obtained through Eqs. (7) and (8).

$$p_i = 1\Big/\max_{1\leqslant k\leqslant m} g_{ki},$$

$$\boldsymbol{X}=\begin{bmatrix} x_{11} & \cdots & x_{1i} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{k1} & \cdots & x_{ki} & \cdots & x_{kn} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mi} & \cdots & x_{mn} \end{bmatrix}, \tag{7}$$

$$\boldsymbol{X}_i = p_i\boldsymbol{G}_i. \tag{8}$$

Definition 10. Let $\boldsymbol{x}_0$ be the reference pattern with n entries (i.e. dependent variable): $\boldsymbol{x}_0=(x_0(1),x_0(2),\ldots,x_0(n))$ and $\boldsymbol{x}_i$, the matrix containing the normalized mapping information of each innovation policy tool to the IIRs, be one of the m patterns with n entries to be compared with the $\boldsymbol{x}_0$, where $\boldsymbol{x}_i$ is written as $\boldsymbol{x}_i=(x_i(1),x_i(2),\ldots,x_i(n))$, $1\leqslant i\leqslant m$. The sequence $\boldsymbol{x}_i$ generally expresses the influencing factor of $\boldsymbol{x}_0$.

Definition 11. Let $\boldsymbol{X}$ be a normalized factor set of grey relations, $\boldsymbol{x}_0\in\boldsymbol{X}$ the referential sequence, and $\boldsymbol{x}_i\in\boldsymbol{X}$ the comparative sequence; with $x_0(k)$ and $x_i(k)$ representing the numerals at point k for $\boldsymbol{x}_0$ and $\boldsymbol{x}_i$, respectively. If $\gamma(x_0(k),x_i(k))$ and $\gamma(\boldsymbol{x}_0,\boldsymbol{x}_i)$ are real numbers, and satisfy the following four grey axioms, then call $\gamma(x_0(k),x_i(k))$ the grey relation coefficient, and the grade of the grey relation $\gamma(\boldsymbol{x}_0,\boldsymbol{x}_i)$ is the average value of $\gamma(x_0(k),x_i(k))$.

1. Norm Interval

   $0<\gamma(x_0(k),x_i(k))\leqslant 1,\ \forall k;\ \gamma(\boldsymbol{x}_0,\boldsymbol{x}_i)=1\ \textit{iff}\ \boldsymbol{x}_0=\boldsymbol{x}_i;$
   $\gamma(x_0,x_i)=0$ iff $x_0,x_i\in\phi;$

   where ϕ is an empty set.
2. Duality symmetric

   $\boldsymbol{x},\boldsymbol{y}\in\boldsymbol{X}\Rightarrow\gamma(\boldsymbol{x},\boldsymbol{y})=\gamma(\boldsymbol{y},\boldsymbol{x})\ \textit{iff}\ \boldsymbol{X}=\{\boldsymbol{x},\boldsymbol{y}\}.$
3. Wholeness

   $\gamma(\boldsymbol{x}_i,\boldsymbol{x}_j)\overset{\text{often}}{\neq}\gamma(\boldsymbol{x}_j,\boldsymbol{x}_i)$ iff $\boldsymbol{X}=\{\boldsymbol{x}_i|i=0,1,\ldots,n\},n>2.$
4. Approachability

   $\gamma(x_0(k),x_i(k))$ decreases when $|(x_0(k)-x_i(k))|$ increases.

Deng also proposed a mathematical equation for the grey relation coefficient, as follows:

$$\gamma(x_0(k),x_i(k)) = \frac{\min\limits_{\forall i}\min\limits_{\forall k}\left|(x_0(k)-x_i(k))\right| + \zeta\max\limits_{\forall i}\max\limits_{\forall k}\left|(x_0(k)-x_i(k))\right|}{\left|(x_0(k)-x_i(k))\right| + \zeta\max\limits_{\forall i}\max\limits_{\forall k}\left|(x_0(k)-x_i(k))\right|}, \tag{9}$$

where ζ is the distinguished coefficient ($\zeta \in [0,1]$). Generally, we pick $\zeta = 0.5$. Detailed explanations of this equation are provided in Appendix B.

Definition 12. If $\gamma(\boldsymbol{x}_0, \boldsymbol{x}_i)$ satisfies the four grey relation axioms, then γ is called the Grey relational map.

Definition 13. If Γ is the entirety of the grey relational map, $\gamma \in \Gamma$ satisfies the four axioms of the grey relation, and **X** is the factor set of the grey relation, then $(\boldsymbol{X}, \Gamma)$ will be called the grey relational space, while γ is the specific map for Γ.

Definition 14. Let $(\boldsymbol{X}, \Gamma)$ be the grey relational space, and if $\gamma(\boldsymbol{x}_0, \boldsymbol{x}_j), \gamma(\boldsymbol{x}_0, \boldsymbol{x}_p), \cdots, \gamma(\boldsymbol{x}_0, \boldsymbol{x}_q)$ satisfy $\gamma(\boldsymbol{x}_0, \boldsymbol{x}_j) > \gamma(\boldsymbol{x}_0, \boldsymbol{x}_p) > \cdots > \gamma(\boldsymbol{x}_0, \boldsymbol{x}_q)$, then we have the Grey relational order: $\boldsymbol{x}_j \succ \boldsymbol{x}_p \succ \cdots \succ \boldsymbol{x}_q$.

When the grey relational coefficient is conducted with respect to innovation policies, we then can derive the grade of the grey relation $\gamma(\boldsymbol{x}_0, \boldsymbol{x}_i)$ between the reference alternative

$$\gamma(\boldsymbol{x}_0, \boldsymbol{x}_i) = \frac{1}{n}\sum_{k=1}^{n} \gamma(x_0(k), x_i(k)). \tag{10}$$

3.4. Cluster analysis

Cluster analysis, also known by the names of segmentation analysis and taxonomy analysis, is a set of techniques for accomplishing the task of partitioning a set of objects into relatively homogeneous subsets, based upon inter-object similarities (Kachigan, 1991). The objective of cluster analysis is to group observations into clusters, such that each cluster is as homogeneous as possible with respect to the clustering variables. The first step in cluster analysis is to select a measure of similarity. Next, a decision is made on the type of clustering technique to be used. Third, the type of clustering method for the selected technique is selected. Fourth, a decision regarding the number of clusters is made. Finally, the cluster solution is interpreted (Sharma, 1996). To apply cluster analysis smoothly, we refined the cluster analysis procedure introduced by Everitt et al. (2001) and produced the essential definitions indicated below.

The basic data for most applications of cluster analysis is the usual $n \times p$ multivariate data matrix, $\boldsymbol{Y}$, containing the variable values describing each object to be clustered; that is

$$\boldsymbol{Y} = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1p} \\ y_{21} & y_{22} & \cdots & y_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ y_{n1} & y_{n2} & \cdots & y_{np} \end{bmatrix}.$$

The entry y_{ij} in $\boldsymbol{Y}$ gives the value of the jth variable on the ith object.

Initially, the data matrix, $\boldsymbol{Y}$, is converted into an $n \times n$ inter-object distance matrix $\boldsymbol{D}$ using the Euclidean distance measure, where

$$\boldsymbol{D} = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{21} & d_{22} & \cdots & d_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ d_{n1} & d_{n2} & \cdots & d_{nn} \end{bmatrix}$$

and

$$d^2_{\alpha\beta} = \sum_{j=1}^{p} (y_{\alpha j} - y_{\beta j})^2 \tag{11}$$

where α and β stand for any two objects, and $x_{\alpha j}$, $x_{\beta j}$ stands for the jth attribute of objects α and β, $1 \leqslant j \leqslant p$ (Tzeng, 1978).

Once the inter-object distance matrix $\boldsymbol{D}$ is derived, the agglomerative procedure in the hierarchical clustering technique will be applied, by forming a series of partitions amongst the data: the first consisting of n single-member 'clusters', and the last consisting of a single group containing all n individuals. At each stage, the methods fuse individuals or groups of individuals, which are closest (or most similar). Here, the distance between groups is defined as that of the closest pair of individuals, where only pairs consisting of one individual from each group are considered, using the nearest-neighbor distance.

Definition 15. The distance between any two clusters, C_f and C_g, can be calculated as

$$h_{fg} = \min(d_{\alpha\beta} | \alpha \in C_f, \beta \in C_g). \tag{12}$$

4. SIP Mall industry background and current innovation policies

According to Worchel (2004), the market scale of SIP already exceeded one billion USD in 2004. Meanwhile, it is predicted that this market will continue steady growth and hit 1.8 billion USD by 2008. Despite the optimistic future of SIP, potential problems regarding SIP transactions that could hinder business have appeared. The complex problems include laws and regulations pertaining to SIP transactions, negotiations over SIP searching and usage rights, technical support including SIP integration into SOCs, SIP maintenance, and application engineering based upon current business models. Apparently, SIP transactions and integrations are not easy. e-Commerce business models for SIP transactions, which can effectively resolve the above-mentioned business, legal, and technical issues, will be most helpful to accelerate industry growth.

In the past, if an SIP user wanted to implement a SOC with SIPs integrated inside, the SIP user had to source the SIPs directly from different SIP providers and/or through different intermediates, including foundry, design service providers, brokers, and distributors, to acquire all the SIP solutions they needed (Fig. 4). Now users can purchase all the SIPs through a single web-based e-Commerce mechanism, called an SIP Mall, and receive all SIP deliverables, business and legal services, and technical support (Fig. 5). When the SIP providers use the e-Commerce mechanism of the SIP Mall to source SIPs, negotiate business terms, define legal contracts, verify SIPs on-line in advance, and obtain pre-verified SIPs, the total time from design to market can be reduced significantly (Fig. 6). SIP providers also can reduce their time effectively through e-Commerce transactions. In the past, SIP providers standardized, verified, and sold SIPs by themselves. After the establishment of the SIP Mall, SIP providers need only to upload their SIPs to the e-Commerce server, and the SIP Mall will finish the SIP simulations, verifications, marketing, sales, and customer services for them (Fig. 7).

The SIP Mall aims to develop a one-stop SIP shopping environment for worldwide customers, update SIP status in a timely manner, attract new business for wafer foundries, shorten time-to-tape-out of SIP customers, serve as an effective SIP marketing channel for worldwide SIP providers, and make the e-Commerce mechanism easy to use.

To provide well-verified SIPs for next generation killer applications, the SIP Mall intends to provide SIPs to design houses, design service companies, and integrated device manufacturers (IDMs). At the same time, the e-Commerce mechanism will co-verify SIPs with foundries and define SIP technology roadmaps with system houses. As a powerful SIP transaction platform, the SIP Mall will serve as an efficient SIP marketing channel for worldwide SIP providers. The SIP Mall will join industry standard definitions, so as to meet the SOC/SIP specification definition requirements. For the software needed for the next generation of killer applications, the SIP Mall will cooperate with software providers to develop-related tools. To develop cost-efficient assembly and test solutions for next generation SOC products, the SIP Mall also will co-work with packaging and testing vendors. Finally, the SIP Mall will cooperate with professional educational institutes. On one hand, SIP Malls will provide SIP-related training. On the other hand, professional education institutions will provide professionals with this e-Commerce mechanism.

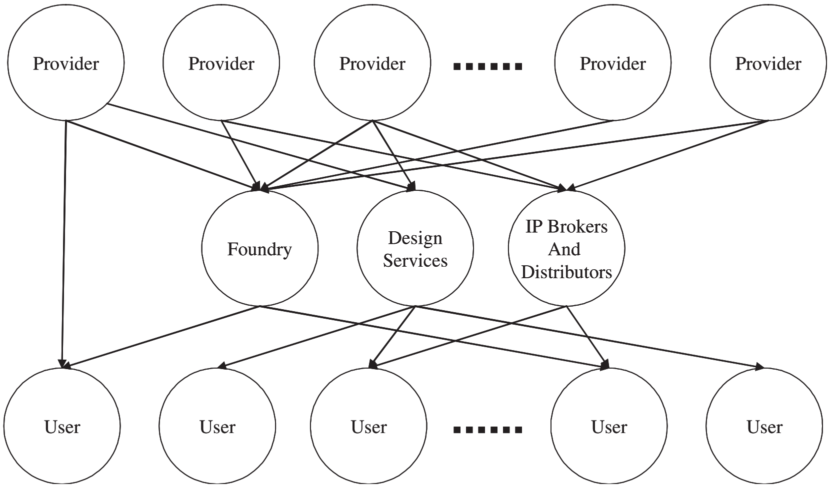

Fig. 4. SIP transactions in the past.

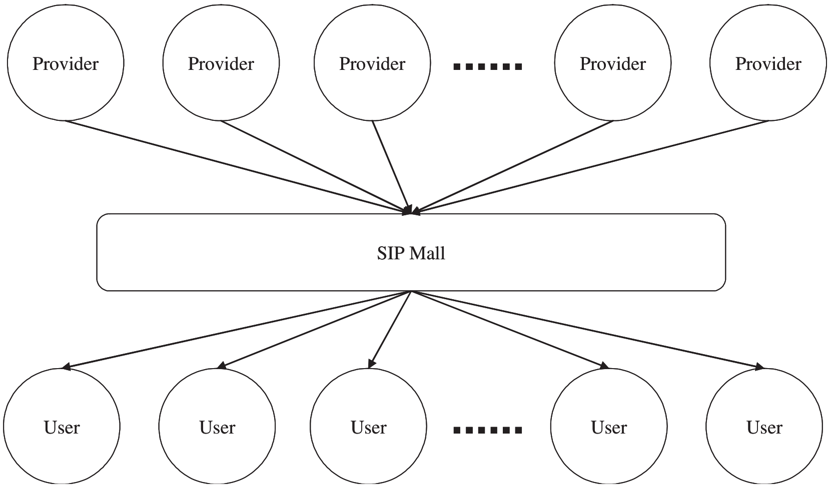

Fig. 5. SIP transactions through SIP Mall era.

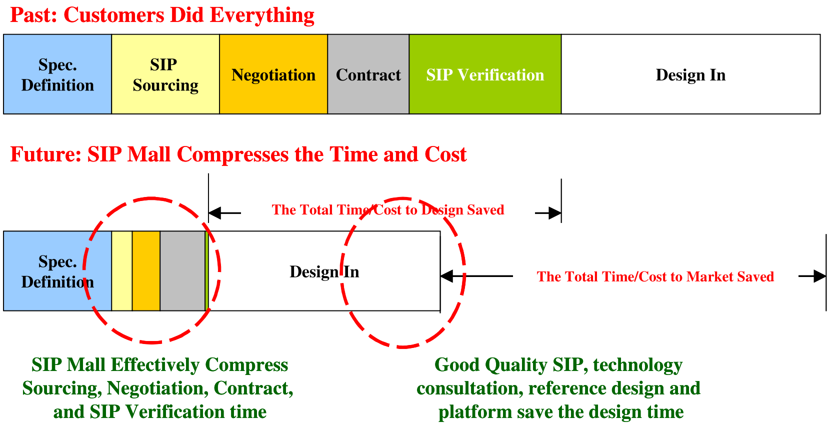

Fig. 6. Concepts of SIP Malls saving customers' time/cost to design and market.

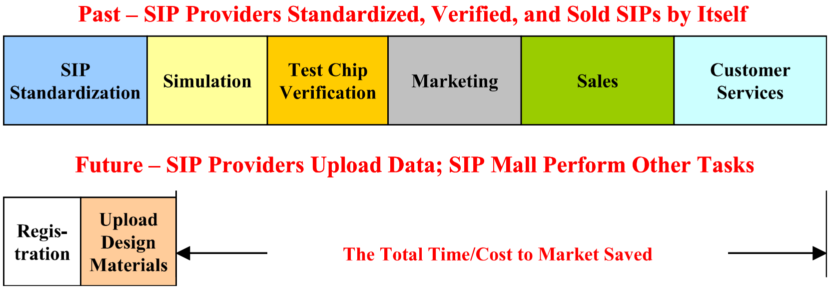

Fig. 7. Concepts of SIP Malls saving providers' time/cost to design and market.

In addition to the United States, several other countries—Japan, South Korea, France, Scotland, and Taiwan—have rolled out SIP Mall programs. Following are brief introductions to each.

4.1. The United States

The Virtual Socket Interface Alliance (VSIA), at www.vsi.org, is the United States' SIP Mall program. It was formed in September of 1996 by a group of major EDA and semiconductor companies. They had two primary goals: first, to establish a unifying vision for the chip industry; and second, to develop the technical standards required to enable the most critical component of that vision: the mix and match of SIP cores from multiple sources. VSIA later expanded that vision to meet the growing needs of the IC industry, by including software and hardware SIP for SOC design; and it recently has restructured the organization by creating a new type of working group, called a Pillar. Pillars address standards issues to improve productivity for SOC and IP developers and users. Currently, there are four Pillars. They cover SIP quality, SIP protection, SIP transfer, and R&D (VSIA, 2006).

4.2. Japan

The IP Trade Center (IPTC), at www.iptc.co.jp, was founded in 2000 as the only Japanese SIP Mall. It was funded by several companies, including Toshiba, Canon, and Matsushita, among others. The mission of IPTC is creating and providing a communication and information-sharing mechanism to promote the reuse and exchange of SIP and design services, thereby enhancing the productivity of SOC and electronic equipment products. IPTC will realize collaboration of SIP and design service providers among member companies, in order to support the complex design and development processes of SOC (IPTC, 2004).

4.3. South Korea

System Integration & Intellectual Property Authoring Center (SIPAC), at www.sipac.org, was established in the KAIST in April 2001 to enhance the competitiveness of the Korean SOC industry, by establishing a web-based SIP trading system, a SIP database and an Internet-based SIP verification and evaluation system, and by joining defining SIP standards (Yoo, 2003).

4.4. France

The France SIP Mall, Design & Reuse (D&R), was founded in October 1997 as a web portal for value-added information in the field of SIP and SOC information. D&R was funded by the Institut National Polytechnique de Grenoble (France) and the Medea project. D&R provides unique services to SIP providers by creating the best communication channels for their customers. For this purpose, D&R holds private catalogs for the major SIP providers. Importing data from the SIP-provider database is automatic and data quality is guaranteed. These private catalogs also are used as an extension of the private micro sites being linked to the D&R portal. For SIP users, D&R rolled out a data intranet import gateway feature in 2001 for feeding users SIP and SOC resource catalogs. Based upon its early experience, D&R licenses technology and services to facilitate SIP sharing and reuse worldwide (Design and Reuse, 2006).

4.5. Scotland

Virtual Component Exchange (VCX) Software Ltd. was established and funded by the Scottish government in October 2000, as the non-profit organization that launched the online VCX. The Exchange aimed at becoming the first regulated buyer-to-buyer exchange for SIP. In September of 2003, VCX was spun off as an independent company to sell database solutions to both SIP buyers and sellers. The independent company also licenses SIPs through its server (Goering, 2003).

4.6. Taiwan

SIP Malls, including SIP Mall at www.sipmall.org and Taiwan IP Mall at www.tipm.com, are operated by Taiwanese design service companies and sponsored by the Taiwanese government's Si-Soft project. Taiwan's SIP Malls aim to provide an online SIP e-Commerce mechanism and SIP commercialization services, wherein users can purchase all SIPs through a single web portal and receive all SIP deliverables, business and legal services, and technical support. SIP providers also can reduce their time effectively through e-Commerce transactions and SIP commercialization services.

Comparing the innovation policies for developing SIP Malls in the above-mentioned six countries, the United States and Japanese SIP Mall programs were sponsored by major semiconductor companies. The United States and Japanese governments did not take significant roles in developing their SIP Malls. Regarding the other four SIP Malls, in South Korea, France, Scotland, and Taiwan, the major applications of environmental innovation policy tools for developing their programs were almost the same. The governments were involved by funding the SIP Mall program either directly (e.g., Scotland), through government sponsored R&D programs (e.g., Taiwan), or through governmental R&D institutes (e.g., South Korea and France). For the supply side policy, South Korea and Taiwan leveraged almost the same tools, including scientific and technical, education as well as information, of which platform and SIP development, plus SIP qualification standard definition by governmental R&D institutes, was the most significant. On the other hand, supply side policy tools of France and Scotland were insignificant. Finally, no country leveraged demand side policy tools as the major approach for developing their SIP Mall programs.

5. An empirical study: the case for Taiwan's SIP Mall industry

The current innovation policy being adopted by the Taiwanese government includes: (1) alleviation of taxation; (2) loan subsidies; (3) supply of information and technological assistance institutions; (4) government procurement; (5) protection of research results; and (6) cultivation of manpower (Shyu and Chiu, 2002). Meanwhile, to support the development of Taiwan's SIP and SIP Mall industry, the government has leveraged several policy tools specifically targeting the SOC and SIP industry.

Even though the government has exerted considerable effort into developing the SIP Mall industry over the past 5 years, Taiwanese SIP Malls still are in the exploratory phase, while SIP sources are limited and SIP transactions through SIP Malls remain few. Meanwhile, Taiwanese SIP Malls are being operated by design service companies. When SIP Mall operations compete for engineering resources needed for customer projects, design service companies always set the priorities of SIP Mall operations as lower priorities, and this has caused SIP Mall inefficiency.

How to define innovation policies that can enhance the innovation capability and competitiveness of Taiwan's SIP Mall industry and enrich Taiwan's star SIP portfolio has become one of the most important issues amongst policy makers.

The authors propose an analytical framework for defining the innovation policy portfolio of Taiwan's SIP Mall industry, by first analyzing current IIRs by means of summarizing opinions from experts using the Delphi method, and then simplifying the complex IIRs using DEMATEL. Finally, the relationships between the simplified IIRs and the innovation policy tools were derived via GRA. Six experts within Taiwan's SIP Mall industry were invited to provide their inputs at each stage of this empirical analysis. Both the details and results of the procedures are presented below.

5.1. IIRs derived by Delphi

Twenty-four IIRs needed for industrial innovation of Taiwan's SIP Mall industry were collected by interviewing experts in government and Taiwan's SIP Mall industry using Delphi procedures. Descriptions of these IIRs as follows:

(1) *e-Commerce capability*: SIP e-Commerce capabilities include the establishment of an e-Commerce infrastructure, public policies and regulations, electronic data interchanges, on-line payments, and security mechanisms. These capabilities definitely will be

critical to define and enable e-Commerce mechanisms, shorten the time to market for SIPs, and enable SIP business.

(2) *Market leadership and customer education*: Technology push is becoming the marketing trend in the IC and SOC industries. Those who have the capacity to educate their customers will win at the end. Market leaders then can define specifications for their next-generation products. With higher market shares and profits from already developed products, market leaders also can generate returns from investments sooner than their competitors. Consequently, more and more resources can be invested into innovation activities to accelerate the time-to-market for next generation products. Thus, market leaders can confirm their situation even longer and to a greater degree.

(3) *Time-to-market capability*: Time-to-market always is the most important factor for vendors seeking to help customers achieve time-to-money. As the complexity of SOCs increases, the ability of vendors to roll out solutions in the shortest time possible is crucial for maintaining customer relationships.

(4) *SIP sourcing capability*: In the SOC era, SIP sourcing has become one of the most important issues in SOC design, since SIP design and reuse already have become one of the most frequent activities. Effective sourcing of SIP can shorten the time-to-design.

(5) *SIP integration service capability*: SIP integration services assist customers implement designs from concept-to-production within the shortest time. SIP integration services also help customers to narrow the gap between system companies and silicon foundries, to enable process technology deployment, and to shorten time-to-design, and therefore, time-to-revenue. For system houses and medium-to small-sized design houses, SIP integration services help customers to finish their SOCs.

(6) *SIP qualification capability*: Well-qualified SIP cores are necessary for SOC success, both in terms of engineering and business. Thus, SIP qualification capabilities of SIP providers are essential for innovation. Typical SIP qualification includes inspections of SIP documentations, specifications, SIP verification results, and SIP pilot run results.

(7) *SIP verification capability*: SIP verification is the design procedure used to verify the functions and timing of SIP cores. Thus, SIP verification capability is as important as SIP qualification with respect to guaranteeing the final success of an SIP.

(8) *Multiple Project Wafer* (*MPW*) *services*: As technology evolves, mask and engineering run costs grow exponentially with each process generation. MPW services aim to reduce IC and SIP developer costs, so as to develop and facilitate faster prototyping by sharing the costs of a common mask set and engineering-run. Moreover, these services encourages innovation, and offers their customers a great opportunity to prove their design, product and market test samples.

(9) *Legal protections*: The SIP business is built on the foundation of IP. Naturally, security is one of the main concerns in the SIP business. One way to secure IP is by using legal procedures, as previously mentioned. However, such methods are not iron clad. As IP trading moves further onto the Internet, better security methods will be needed (Gajski et al., 2000).

(10) *Funding capability*: IC and SIP designs have become more and more complicated in advanced processes. The most up-to-date IC design flows and EDA tools are required to achieve higher speed, lower power, and lower cost. MPW blocks in advanced processes are more expensive. Meanwhile, setting up the e-Commerce infrastructure requires greater investments in servers and firewalls. How to leverage various funding tools, including loans, venture capital investments, initial public offerings (IPOs), and changeable bonds (CBs) has become the most important factor influencing operation efficiency.

(11) *Establishment of SIP know-how:* Domain knowledge regarding SIP design specification, integration, testing, mass production, and application can guarantee proper SIP applications and transactions.

(12) *Establishment of electronic systems know-how*: SOC needs a great deal of electronic system know-how to achieve the final successful integration of SIP applications into chips and electronic systems. The establishment of electronic system know-how also is important for SIP success in engineering and business.

(13) *Joint development capability*: Individual organizations no longer can rely on their own resources to compete in today's world. Rather, they should look for strategic interactions that will allow them to leverage internal resources effectively, by investing in core competencies and contracting out other knowledge domains (Sobrero and Roberts, 2002). Various specifications for embedded processors, peripherals, memories, analog, and mixed signal cores are emerging as future needs for 3C (computer, communication, and computer) applications. There is almost no single company—no matter how professional an SIP provider, fabless IC design house, semiconductor foundry, or even an IDM is—that can afford the human resources and R&D capabilities necessary to develop every SIP, especially at a time when the time-to-market of SOC products is shortening rapidly. Hence, a joint development capability (including technology transfer) has become a key aspect of SIP innovation.

(14) *SIP porting capability*: Moving an SIP to the existing process of another semiconductor fab always involves redesign and extensive product development, and often multiple expensive iterations. A better way is to 'port' the process; i.e., move it cell by cell without

changing the SIP created to use it. By adopting the basic methods used in the silicon industry and paying attention to process details that affect performance, successful porting is faster, much less expensive, and less disruptive to the flow of the product. Porting also results in multiple qualified fab sites for a given SIP. An added benefit is that multiple geographically separated production facilities make the supply chain immune to disruption by natural disaster or power interruptions. Porting also eliminates the need for customers to re-qualify a product containing chips from a new source (Williams et al., 2002).

(15) *Strategic alliance capability*: Strategic alliances typically take the form of an agreement between two or more firms to work together for a specific project, and tend to focus on near-market development projects (Tidd and Brocklehurst, 1993). SIP Malls should have strong strategic alliances with research institutes, universities, design service companies, and system houses to access the most up-to-date techniques and domain know-how regarding system application engineering.

(16) *Close relationship with foundries*: SIPs, especially mixed signal and analog SIPs from professional SIP providers, always target specific processes of major foundries—for example, TSMC, UMC or IBM—to target major foundry SOC customers in advanced processes. Close relationships with foundries are essential for SIP Malls, so that they can have a SIP verification, qualification and marketing channel.

(17) *Close relationships with design service companies*: Design service companies provide SOC integration, MPW, and SOC turnkey services, which may serve as bridges between customers and SIP Malls. A close relationship with design service companies may guarantee SIP integration, verification, and qualification success.

(18) *Close relationships with customers:* Customer relationship management is a strategy used to learn more about customers' needs and behaviors, so as to develop stronger relationships with them.

(19) *Close relationships with SIP providers*: The close relationship between an SIP Mall and SIP providers may guarantee that the SIP Mall accesses the most up-to-date SIP information, including SIP specifications, simulation models, product roadmaps, and business models. This information may assist customers in implementing their SOCs correctly, using the most advanced SIPs and design information.

(20) *Marketing capability*: Strong SIP Mall marketing capability includes SIP product and service definitions, pricing, promotion and advertisement, competitive analysis, and more.

(21) *Design service capabilities*: The design service capabilities of SOC refers to the capabilities to provide customers who finish SOC specification design or SOC circuit design with the remaining procedures or processes required for SOC commercialization. These detailed procedures include front-end design, back-end (place and layout), and turnkey (tape-out of the layout to semiconductor wafer fab for SOC fabrication) services. The above-mentioned design service capabilities definitely are helpful for SIP Mall success, since strong design service capability implies strong SIP integration capability, a key factor in SOC success.

(22) *SIP safeguard techniques*: SIP safeguard techniques mean watermarks and other approaches implemented in SIPs to prevent the illegal use or duplication of SIPs.

(23) *R&D knowledge management capability*: The modern R&D system magnifies the role of information technology (Barthe's and Tacla, 2002; Dennis et al., 1998) and emphasizes the platform and architecture of the whole R&D system. In this regard, knowledge management (KM) becomes an indispensable requisite of the fourth generation R&D. In fact, the R&D process can be considered primarily a knowledge management process, because it transforms information on technological advancements and market demands into knowledge. That knowledge then can be used to develop new product concepts and process designs (Kerssens-Van et al., 1996; Nieto, 2002; Park and Kim, 2004).

(24) *Human resources management capability*: ICs have become one of the fastest growing and most highly invested industries in Taiwan. In order to keep pace with the technological advancements in nanometer semiconductor manufacturing, IC design and SOC techniques also are evolving. This evolution is leading to a strong demand from the industry for a large number of well-trained IC design engineers, as well as supportive human resources in business and law (Advisor Office of Ministry of Education, 2004).

5.2. IIRs reduction by DEMATEL

Since the 24 IIRs summarized using the above Delphi process seem too complicated to be analyzed, the key innovation requirements will be deducted using the DEMATEL method that was introduced in Section 3.2. First, the direct relation/influence matrix $\boldsymbol{A}$ is introduced, as shown in Fig. 8. After that, the direct relation/influence matrix $\boldsymbol{A}$ is normalized, based upon Eq. (1) and the normalized direct relation/influence matrix $\boldsymbol{N}$ is shown in Fig. 9. Finally, the direct/indirect matrix is deducted, based on Eq. (3) and shown in Fig. 10. The causal diagram of the total relationships is shown in Fig. 11 where major IIRs are deducted by setting the threshold value at 0.10. The symbols being used to represent the IIRs are summarized in Table 2. It is obvious that the major IIRs are IIR8, IIR9, IIR11, IIR12, IIR15, IIR16, IIR20, IIR22, IIR23, and IIR24, based upon the values of $(r_i{-}c_i)$. These values stand for MPW Services (IIR8), legal protections (IIR9), SIP know-how establishment (IIR11), electronic systems know-how establishment (IIR12), strategic alliance capability (IIR15), close relationship with foundries (IIR16), marketing capability (IIR20), SIP safeguard techniques (IIR22), knowledge management capability (IIR23), and human resources management capability (IIR24).

5.3. Mapping-derived IIRs to innovation policy tools using GRA

GRA is used here to derive the relationships between IIRs and innovation policy tools. The initial relationship matrix $\boldsymbol{G}$, a 12×10 matrix that maps the relationship between 12 innovation policy tools and 10 major IIRs, was obtained by collecting opinions from experts (Fig. 12). The symbols being used to represent the policy tools are introduced in Table 3. The normalized relationship matrix $\boldsymbol{X}$ then was derived based upon Eqs. 7 and 8 (Fig. 13).

Let the value of each element of $\boldsymbol{x}_0$, the reference pattern, be '1,' which stands for the best case for the elements in the normalized correlation matrix. By setting the distinguished coefficient ζ as 0.5, the Grey relation coefficients were derived using Eq. (9). Finally, the grades of Grey relation

$$A=\begin{bmatrix}
0.000 & 8.167 & 6.500 & 4.333 & 4.000 & 3.667 & 3.833 & 3.500 & 4.000 & 4.833 & 4.000 & 4.667 & 4.167 & 4.667 & 4.500 & 5.333 & 5.000 & 4.833 & 5.333 & 8.833 & 3.667 & 3.333 & 4.500 & 3.833 \\
6.000 & 0.000 & 5.667 & 5.833 & 5.167 & 6.000 & 5.167 & 5.000 & 4.833 & 7.833 & 5.667 & 5.833 & 5.500 & 5.500 & 5.667 & 4.500 & 5.000 & 6.833 & 6.333 & 6.667 & 4.500 & 4.833 & 4.333 & 4.833 \\
4.333 & 7.000 & 0.000 & 5.167 & 5.167 & 4.000 & 4.500 & 4.167 & 2.333 & 6.500 & 3.833 & 5.333 & 5.000 & 4.667 & 4.333 & 5.167 & 5.833 & 5.833 & 6.167 & 5.167 & 4.167 & 2.833 & 2.667 & 1.833 \\
3.833 & 6.500 & 9.000 & 0.000 & 6.667 & 5.000 & 4.500 & 2.667 & 2.500 & 5.167 & 5.333 & 4.333 & 4.667 & 5.167 & 4.667 & 5.000 & 5.333 & 6.167 & 6.167 & 4.667 & 6.833 & 3.500 & 3.333 & 1.833 \\
4.333 & 6.667 & 9.000 & 4.500 & 0.000 & 5.000 & 4.667 & 2.333 & 2.667 & 6.167 & 4.667 & 5.167 & 4.500 & 5.833 & 3.333 & 5.333 & 4.000 & 6.000 & 6.000 & 3.333 & 8.167 & 3.667 & 3.333 & 1.167 \\
5.000 & 8.167 & 8.000 & 5.167 & 6.167 & 0.000 & 4.500 & 4.167 & 2.667 & 5.833 & 4.833 & 3.333 & 6.000 & 5.000 & 3.333 & 5.333 & 4.333 & 6.167 & 8.000 & 3.333 & 7.000 & 2.833 & 3.167 & 1.000 \\
4.500 & 7.500 & 8.167 & 4.167 & 7.333 & 8.667 & 0.000 & 3.167 & 3.000 & 8.500 & 4.500 & 3.333 & 6.167 & 6.000 & 3.333 & 6.833 & 4.333 & 7.667 & 5.333 & 5.000 & 6.833 & 3.167 & 3.167 & 1.833 \\
2.167 & 5.167 & 7.167 & 3.167 & 6.500 & 7.000 & 7.833 & 0.000 & 2.167 & 6.333 & 5.000 & 4.833 & 6.667 & 7.833 & 4.833 & 6.500 & 6.667 & 6.333 & 5.500 & 5.167 & 7.833 & 2.500 & 2.333 & 0.833 \\
6.333 & 4.833 & 5.667 & 2.833 & 3.667 & 3.167 & 2.833 & 3.333 & 0.000 & 4.333 & 2.833 & 3.167 & 3.833 & 3.500 & 4.000 & 2.333 & 2.667 & 2.833 & 2.500 & 2.500 & 3.000 & 2.333 & 2.167 & 1.167 \\
7.833 & 7.167 & 5.833 & 5.667 & 7.167 & 7.500 & 7.667 & 7.333 & 4.167 & 0.000 & 6.000 & 5.667 & 4.500 & 5.833 & 2.833 & 3.500 & 3.833 & 3.500 & 5.333 & 7.000 & 4.667 & 4.833 & 4.167 & 4.000 \\
4.000 & 5.833 & 6.500 & 7.833 & 8.000 & 8.000 & 8.000 & 3.333 & 4.333 & 4.833 & 0.000 & 4.833 & 5.500 & 8.167 & 5.000 & 7.000 & 8.000 & 6.667 & 7.333 & 5.667 & 5.667 & 4.000 & 3.500 & 1.833 \\
4.000 & 5.833 & 6.167 & 7.667 & 7.833 & 7.667 & 7.667 & 2.833 & 3.000 & 5.167 & 6.167 & 0.000 & 5.167 & 6.500 & 3.333 & 4.500 & 7.333 & 6.667 & 5.667 & 5.000 & 5.500 & 3.667 & 3.500 & 1.833 \\
4.000 & 7.167 & 6.500 & 3.500 & 4.667 & 3.833 & 4.500 & 2.833 & 3.000 & 4.833 & 5.167 & 4.667 & 0.000 & 5.667 & 7.500 & 7.167 & 7.333 & 7.500 & 7.833 & 4.167 & 6.667 & 3.833 & 4.333 & 2.000 \\
4.000 & 6.667 & 6.833 & 3.833 & 6.000 & 5.667 & 5.167 & 3.667 & 2.500 & 5.500 & 4.500 & 3.500 & 4.833 & 0.000 & 4.833 & 5.333 & 6.500 & 5.667 & 6.500 & 3.000 & 6.833 & 3.500 & 4.000 & 3.000 \\
4.667 & 7.333 & 5.167 & 6.333 & 4.667 & 3.833 & 4.333 & 4.667 & 3.333 & 5.167 & 4.833 & 4.167 & 7.000 & 3.167 & 0.000 & 7.000 & 6.500 & 7.667 & 8.333 & 3.667 & 4.000 & 3.167 & 3.500 & 2.000 \\
3.500 & 5.833 & 6.167 & 4.833 & 7.167 & 6.000 & 6.167 & 7.667 & 3.000 & 6.333 & 6.333 & 4.333 & 5.667 & 6.500 & 4.833 & 0.000 & 6.167 & 5.333 & 5.333 & 3.833 & 5.000 & 2.833 & 3.500 & 3.000 \\
2.833 & 5.667 & 6.167 & 5.667 & 8.500 & 6.000 & 5.333 & 4.167 & 2.500 & 5.500 & 5.167 & 4.333 & 5.667 & 6.167 & 6.000 & 4.167 & 0.000 & 6.000 & 5.167 & 4.333 & 6.833 & 2.833 & 3.167 & 2.500 \\
6.333 & 7.500 & 6.500 & 4.833 & 4.167 & 4.167 & 4.500 & 3.333 & 3.000 & 7.000 & 5.167 & 7.500 & 6.500 & 3.500 & 6.167 & 4.000 & 4.000 & 0.000 & 5.333 & 6.500 & 3.167 & 3.167 & 3.500 & 2.000 \\
6.333 & 7.333 & 7.167 & 7.333 & 6.667 & 6.167 & 5.833 & 4.000 & 2.167 & 6.667 & 8.000 & 6.333 & 6.500 & 4.333 & 6.000 & 4.333 & 5.500 & 4.500 & 0.000 & 3.833 & 7.167 & 3.833 & 3.833 & 2.500 \\
6.167 & 8.500 & 6.667 & 4.167 & 6.000 & 5.000 & 5.000 & 4.667 & 2.167 & 6.833 & 3.667 & 2.833 & 4.667 & 4.500 & 5.333 & 4.167 & 4.000 & 7.500 & 4.667 & 0.000 & 2.500 & 2.167 & 4.000 & 3.000 \\
5.333 & 5.667 & 5.500 & 4.333 & 5.000 & 6.000 & 6.667 & 4.667 & 2.667 & 5.333 & 4.667 & 4.167 & 4.500 & 5.500 & 3.667 & 6.167 & 6.167 & 6.667 & 6.500 & 2.500 & 0.000 & 3.500 & 3.500 & 3.667 \\
7.333 & 6.000 & 5.833 & 4.000 & 5.000 & 3.500 & 3.833 & 4.333 & 4.000 & 6.000 & 4.167 & 3.167 & 3.667 & 3.333 & 3.500 & 5.000 & 4.833 & 5.500 & 7.167 & 2.500 & 3.000 & 0.000 & 3.833 & 2.833 \\
5.667 & 5.667 & 6.333 & 7.167 & 5.833 & 5.167 & 5.500 & 4.333 & 4.167 & 5.167 & 6.500 & 5.500 & 4.333 & 4.000 & 3.833 & 3.167 & 3.833 & 5.167 & 5.000 & 3.000 & 5.000 & 3.167 & 0.000 & 4.667 \\
8.667 & 9.000 & 7.833 & 8.500 & 9.333 & 8.833 & 9.167 & 6.667 & 5.333 & 7.667 & 9.000 & 8.667 & 8.333 & 8.167 & 6.333 & 5.333 & 6.833 & 6.833 & 7.167 & 6.000 & 7.333 & 6.500 & 4.600 & 0.000
\end{bmatrix}$$

Fig. 8. The direct relation/influence matrix $\boldsymbol{A}$.

$$N=\begin{bmatrix}
0.000 & 0.044 & 0.035 & 0.023 & 0.022 & 0.020 & 0.021 & 0.019 & 0.022 & 0.026 & 0.022 & 0.025 & 0.023 & 0.025 & 0.024 & 0.029 & 0.027 & 0.026 & 0.029 & 0.048 & 0.020 & 0.018 & 0.024 & 0.021 \\
0.032 & 0.000 & 0.031 & 0.032 & 0.028 & 0.032 & 0.028 & 0.027 & 0.026 & 0.042 & 0.031 & 0.032 & 0.030 & 0.030 & 0.031 & 0.024 & 0.027 & 0.037 & 0.034 & 0.036 & 0.024 & 0.026 & 0.023 & 0.026 \\
0.023 & 0.038 & 0.000 & 0.028 & 0.028 & 0.022 & 0.024 & 0.023 & 0.013 & 0.035 & 0.021 & 0.029 & 0.027 & 0.025 & 0.023 & 0.028 & 0.032 & 0.032 & 0.033 & 0.028 & 0.023 & 0.015 & 0.014 & 0.010 \\
0.021 & 0.035 & 0.049 & 0.000 & 0.036 & 0.027 & 0.024 & 0.014 & 0.014 & 0.028 & 0.029 & 0.023 & 0.025 & 0.028 & 0.025 & 0.027 & 0.029 & 0.033 & 0.033 & 0.025 & 0.037 & 0.019 & 0.018 & 0.010 \\
0.023 & 0.036 & 0.049 & 0.024 & 0.000 & 0.027 & 0.025 & 0.013 & 0.014 & 0.033 & 0.025 & 0.028 & 0.024 & 0.032 & 0.018 & 0.029 & 0.022 & 0.032 & 0.032 & 0.018 & 0.044 & 0.020 & 0.018 & 0.006 \\
0.027 & 0.044 & 0.043 & 0.028 & 0.033 & 0.000 & 0.024 & 0.023 & 0.014 & 0.032 & 0.026 & 0.018 & 0.032 & 0.027 & 0.018 & 0.029 & 0.023 & 0.033 & 0.043 & 0.018 & 0.038 & 0.015 & 0.017 & 0.005 \\
0.024 & 0.041 & 0.044 & 0.023 & 0.040 & 0.047 & 0.000 & 0.017 & 0.016 & 0.046 & 0.024 & 0.018 & 0.033 & 0.032 & 0.018 & 0.037 & 0.023 & 0.041 & 0.029 & 0.027 & 0.037 & 0.017 & 0.017 & 0.010 \\
0.012 & 0.028 & 0.039 & 0.017 & 0.035 & 0.038 & 0.042 & 0.000 & 0.012 & 0.034 & 0.027 & 0.026 & 0.036 & 0.042 & 0.026 & 0.035 & 0.036 & 0.034 & 0.030 & 0.028 & 0.042 & 0.014 & 0.013 & 0.005 \\
0.034 & 0.026 & 0.031 & 0.015 & 0.020 & 0.017 & 0.015 & 0.018 & 0.000 & 0.023 & 0.015 & 0.017 & 0.021 & 0.019 & 0.022 & 0.013 & 0.014 & 0.015 & 0.014 & 0.014 & 0.016 & 0.013 & 0.012 & 0.006 \\
0.042 & 0.039 & 0.032 & 0.031 & 0.039 & 0.041 & 0.041 & 0.040 & 0.023 & 0.000 & 0.032 & 0.031 & 0.024 & 0.032 & 0.015 & 0.019 & 0.021 & 0.019 & 0.029 & 0.038 & 0.025 & 0.026 & 0.023 & 0.022 \\
0.022 & 0.032 & 0.035 & 0.042 & 0.043 & 0.043 & 0.043 & 0.018 & 0.023 & 0.026 & 0.000 & 0.026 & 0.030 & 0.044 & 0.027 & 0.038 & 0.043 & 0.036 & 0.040 & 0.031 & 0.031 & 0.022 & 0.019 & 0.010 \\
0.022 & 0.032 & 0.033 & 0.041 & 0.042 & 0.041 & 0.041 & 0.015 & 0.016 & 0.028 & 0.033 & 0.000 & 0.028 & 0.035 & 0.018 & 0.024 & 0.040 & 0.036 & 0.031 & 0.027 & 0.030 & 0.020 & 0.019 & 0.010 \\
0.022 & 0.039 & 0.035 & 0.019 & 0.025 & 0.021 & 0.024 & 0.015 & 0.016 & 0.026 & 0.028 & 0.025 & 0.000 & 0.031 & 0.041 & 0.039 & 0.040 & 0.041 & 0.042 & 0.023 & 0.036 & 0.021 & 0.023 & 0.011 \\
0.022 & 0.036 & 0.037 & 0.021 & 0.032 & 0.031 & 0.028 & 0.020 & 0.014 & 0.030 & 0.024 & 0.019 & 0.026 & 0.000 & 0.026 & 0.029 & 0.035 & 0.031 & 0.035 & 0.016 & 0.037 & 0.019 & 0.022 & 0.016 \\
0.025 & 0.040 & 0.028 & 0.034 & 0.025 & 0.021 & 0.023 & 0.025 & 0.018 & 0.028 & 0.026 & 0.023 & 0.038 & 0.017 & 0.000 & 0.038 & 0.035 & 0.041 & 0.045 & 0.020 & 0.022 & 0.017 & 0.019 & 0.011 \\
0.019 & 0.032 & 0.033 & 0.026 & 0.039 & 0.032 & 0.033 & 0.041 & 0.016 & 0.034 & 0.034 & 0.023 & 0.031 & 0.035 & 0.026 & 0.000 & 0.033 & 0.029 & 0.029 & 0.021 & 0.027 & 0.015 & 0.019 & 0.016 \\
0.015 & 0.031 & 0.033 & 0.031 & 0.046 & 0.032 & 0.029 & 0.023 & 0.014 & 0.030 & 0.028 & 0.023 & 0.031 & 0.033 & 0.032 & 0.023 & 0.000 & 0.032 & 0.028 & 0.023 & 0.037 & 0.015 & 0.017 & 0.014 \\
0.034 & 0.041 & 0.035 & 0.026 & 0.023 & 0.023 & 0.024 & 0.018 & 0.016 & 0.038 & 0.028 & 0.041 & 0.035 & 0.019 & 0.033 & 0.022 & 0.022 & 0.000 & 0.029 & 0.035 & 0.017 & 0.017 & 0.019 & 0.011 \\
0.034 & 0.040 & 0.039 & 0.040 & 0.036 & 0.033 & 0.032 & 0.022 & 0.012 & 0.036 & 0.043 & 0.034 & 0.035 & 0.023 & 0.032 & 0.023 & 0.030 & 0.024 & 0.000 & 0.021 & 0.039 & 0.021 & 0.021 & 0.014 \\
0.033 & 0.046 & 0.036 & 0.023 & 0.032 & 0.027 & 0.027 & 0.025 & 0.012 & 0.037 & 0.020 & 0.015 & 0.025 & 0.024 & 0.029 & 0.023 & 0.022 & 0.041 & 0.025 & 0.000 & 0.014 & 0.012 & 0.022 & 0.016 \\
0.029 & 0.031 & 0.030 & 0.023 & 0.027 & 0.032 & 0.036 & 0.025 & 0.014 & 0.029 & 0.025 & 0.023 & 0.024 & 0.030 & 0.020 & 0.033 & 0.033 & 0.036 & 0.035 & 0.014 & 0.000 & 0.019 & 0.019 & 0.020 \\
0.040 & 0.032 & 0.032 & 0.022 & 0.027 & 0.019 & 0.021 & 0.023 & 0.022 & 0.032 & 0.023 & 0.017 & 0.020 & 0.018 & 0.019 & 0.027 & 0.026 & 0.030 & 0.039 & 0.014 & 0.016 & 0.000 & 0.021 & 0.015 \\
0.031 & 0.031 & 0.034 & 0.039 & 0.032 & 0.028 & 0.030 & 0.023 & 0.023 & 0.028 & 0.035 & 0.030 & 0.023 & 0.022 & 0.021 & 0.017 & 0.021 & 0.028 & 0.027 & 0.016 & 0.027 & 0.017 & 0.000 & 0.025 \\
0.047 & 0.049 & 0.042 & 0.046 & 0.050 & 0.048 & 0.050 & 0.036 & 0.029 & 0.041 & 0.049 & 0.047 & 0.045 & 0.044 & 0.034 & 0.029 & 0.037 & 0.037 & 0.039 & 0.032 & 0.040 & 0.035 & 0.025 & 0.000
\end{bmatrix}$$

Fig. 9. The normalized direct relation/influence matrix $\boldsymbol{N}$.

$$\boldsymbol{T}=\begin{bmatrix}
0.043 & 0.100 & 0.090 & 0.067 & 0.073 & 0.067 & 0.067 & 0.055 & 0.049 & 0.076 & 0.065 & 0.065 & 0.068 & 0.069 & 0.063 & 0.071 & 0.072 & 0.076 & 0.079 & 0.086 & 0.065 & 0.047 & 0.054 & 0.042 \\
0.081 & 0.066 & 0.096 & 0.083 & 0.087 & 0.086 & 0.081 & 0.068 & 0.057 & 0.099 & 0.081 & 0.078 & 0.082 & 0.081 & 0.076 & 0.074 & 0.079 & 0.094 & 0.092 & 0.081 & 0.077 & 0.060 & 0.058 & 0.050 \\
0.063 & 0.092 & 0.055 & 0.070 & 0.077 & 0.068 & 0.068 & 0.057 & 0.039 & 0.083 & 0.063 & 0.068 & 0.070 & 0.068 & 0.061 & 0.069 & 0.075 & 0.080 & 0.081 & 0.066 & 0.068 & 0.044 & 0.044 & 0.031 \\
0.064 & 0.092 & 0.105 & 0.045 & 0.087 & 0.075 & 0.071 & 0.050 & 0.041 & 0.079 & 0.073 & 0.064 & 0.070 & 0.073 & 0.065 & 0.071 & 0.075 & 0.084 & 0.084 & 0.065 & 0.083 & 0.049 & 0.049 & 0.032 \\
0.065 & 0.091 & 0.103 & 0.067 & 0.051 & 0.074 & 0.070 & 0.048 & 0.041 & 0.082 & 0.068 & 0.068 & 0.068 & 0.076 & 0.057 & 0.071 & 0.067 & 0.081 & 0.082 & 0.057 & 0.088 & 0.049 & 0.048 & 0.028 \\
0.070 & 0.101 & 0.099 & 0.073 & 0.084 & 0.049 & 0.071 & 0.059 & 0.041 & 0.083 & 0.070 & 0.060 & 0.077 & 0.073 & 0.058 & 0.073 & 0.069 & 0.084 & 0.094 & 0.059 & 0.084 & 0.045 & 0.048 & 0.027 \\
0.071 & 0.103 & 0.105 & 0.071 & 0.095 & 0.098 & 0.051 & 0.056 & 0.046 & 0.101 & 0.072 & 0.063 & 0.082 & 0.081 & 0.061 & 0.084 & 0.073 & 0.095 & 0.085 & 0.070 & 0.087 & 0.050 & 0.051 & 0.034 \\
0.058 & 0.090 & 0.099 & 0.065 & 0.090 & 0.089 & 0.091 & 0.039 & 0.041 & 0.088 & 0.074 & 0.069 & 0.084 & 0.090 & 0.068 & 0.082 & 0.085 & 0.089 & 0.085 & 0.070 & 0.092 & 0.046 & 0.046 & 0.028 \\
0.062 & 0.065 & 0.069 & 0.045 & 0.054 & 0.049 & 0.046 & 0.042 & 0.019 & 0.057 & 0.045 & 0.045 & 0.052 & 0.050 & 0.049 & 0.043 & 0.045 & 0.050 & 0.049 & 0.042 & 0.047 & 0.033 & 0.033 & 0.021 \\
0.089 & 0.103 & 0.096 & 0.081 & 0.097 & 0.095 & 0.093 & 0.079 & 0.053 & 0.058 & 0.081 & 0.076 & 0.075 & 0.083 & 0.060 & 0.069 & 0.073 & 0.077 & 0.087 & 0.083 & 0.078 & 0.059 & 0.057 & 0.046 \\
0.072 & 0.100 & 0.102 & 0.094 & 0.103 & 0.099 & 0.097 & 0.060 & 0.055 & 0.087 & 0.053 & 0.074 & 0.084 & 0.097 & 0.074 & 0.089 & 0.096 & 0.096 & 0.100 & 0.077 & 0.087 & 0.057 & 0.055 & 0.036 \\
0.068 & 0.094 & 0.095 & 0.089 & 0.098 & 0.092 & 0.090 & 0.054 & 0.045 & 0.084 & 0.080 & 0.045 & 0.077 & 0.084 & 0.061 & 0.072 & 0.089 & 0.091 & 0.087 & 0.070 & 0.081 & 0.052 & 0.052 & 0.034 \\
0.067 & 0.099 & 0.094 & 0.067 & 0.080 & 0.072 & 0.073 & 0.054 & 0.045 & 0.080 & 0.075 & 0.068 & 0.049 & 0.079 & 0.083 & 0.085 & 0.088 & 0.094 & 0.096 & 0.065 & 0.085 & 0.052 & 0.055 & 0.034 \\
0.065 & 0.093 & 0.093 & 0.066 & 0.083 & 0.079 & 0.075 & 0.056 & 0.041 & 0.081 & 0.068 & 0.060 & 0.072 & 0.046 & 0.066 & 0.073 & 0.081 & 0.082 & 0.086 & 0.056 & 0.083 & 0.049 & 0.053 & 0.038 \\
0.068 & 0.098 & 0.086 & 0.079 & 0.078 & 0.070 & 0.071 & 0.062 & 0.046 & 0.080 & 0.071 & 0.065 & 0.084 & 0.064 & 0.042 & 0.082 & 0.082 & 0.092 & 0.097 & 0.061 & 0.070 & 0.048 & 0.050 & 0.033 \\
0.064 & 0.093 & 0.093 & 0.073 & 0.093 & 0.083 & 0.082 & 0.078 & 0.045 & 0.088 & 0.080 & 0.066 & 0.079 & 0.083 & 0.068 & 0.048 & 0.082 & 0.083 & 0.084 & 0.064 & 0.077 & 0.047 & 0.052 & 0.039 \\
0.059 & 0.090 & 0.091 & 0.076 & 0.098 & 0.081 & 0.076 & 0.059 & 0.042 & 0.082 & 0.073 & 0.065 & 0.077 & 0.079 & 0.072 & 0.068 & 0.048 & 0.084 & 0.081 & 0.064 & 0.085 & 0.046 & 0.048 & 0.036 \\
0.076 & 0.098 & 0.091 & 0.071 & 0.075 & 0.071 & 0.071 & 0.054 & 0.043 & 0.088 & 0.072 & 0.081 & 0.080 & 0.065 & 0.072 & 0.066 & 0.068 & 0.052 & 0.080 & 0.075 & 0.064 & 0.047 & 0.050 & 0.033 \\
0.081 & 0.104 & 0.103 & 0.090 & 0.094 & 0.087 & 0.084 & 0.062 & 0.043 & 0.093 & 0.092 & 0.080 & 0.086 & 0.075 & 0.076 & 0.073 & 0.082 & 0.082 & 0.059 & 0.067 & 0.091 & 0.055 & 0.056 & 0.039 \\
0.074 & 0.101 & 0.091 & 0.066 & 0.081 & 0.073 & 0.072 & 0.060 & 0.039 & 0.086 & 0.063 & 0.055 & 0.069 & 0.068 & 0.067 & 0.065 & 0.066 & 0.090 & 0.075 & 0.040 & 0.060 & 0.041 & 0.052 & 0.037 \\
0.072 & 0.089 & 0.087 & 0.068 & 0.079 & 0.080 & 0.082 & 0.061 & 0.042 & 0.080 & 0.070 & 0.064 & 0.070 & 0.076 & 0.060 & 0.077 & 0.079 & 0.087 & 0.086 & 0.055 & 0.048 & 0.049 & 0.050 & 0.042 \\
0.079 & 0.084 & 0.084 & 0.063 & 0.074 & 0.063 & 0.064 & 0.056 & 0.047 & 0.078 & 0.064 & 0.055 & 0.062 & 0.060 & 0.056 & 0.067 & 0.068 & 0.076 & 0.085 & 0.052 & 0.059 & 0.028 & 0.049 & 0.035 \\
0.074 & 0.089 & 0.091 & 0.084 & 0.084 & 0.076 & 0.077 & 0.059 & 0.050 & 0.079 & 0.079 & 0.071 & 0.069 & 0.068 & 0.061 & 0.061 & 0.068 & 0.079 & 0.079 & 0.057 & 0.074 & 0.047 & 0.031 & 0.046 \\
0.111 & 0.136 & 0.129 & 0.113 & 0.128 & 0.120 & 0.120 & 0.090 & 0.070 & 0.118 & 0.115 & 0.108 & 0.114 & 0.113 & 0.094 & 0.096 & 0.107 & 0.115 & 0.117 & 0.093 & 0.111 & 0.080 & 0.072 & 0.033
\end{bmatrix}$$

Fig. 10. The direct/indirect matrix $\boldsymbol{T}$.

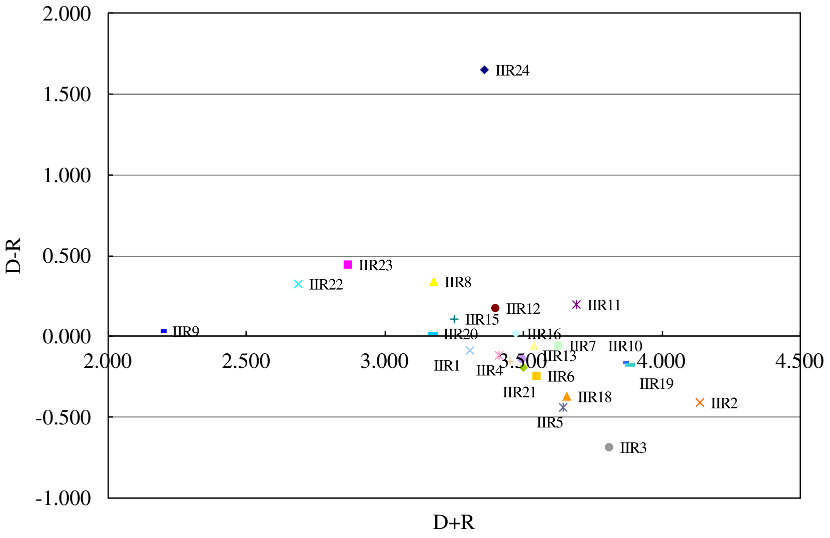

Fig. 11. The causal diagram of total relationship.

$\gamma(\boldsymbol{x}_0, \boldsymbol{x}_i)$ were derived using Eq. (10) (see Table 4). We established the result that

$$\text{P2} \succ \text{P3} \succ \text{P1} \succ \text{P4} \succ \text{P7} \succ \text{P5} \succ \text{P6} \succ \text{P8} \succ \text{P10} \succ \text{P9} \succ \text{P12} \succ \text{P11},$$

which stands for the policy priorities for developing the SIP industry.

To cluster the above policy tools so as to establish the policy portfolios, a 1×12 multivariate data matrix $\boldsymbol{Y}$ containing the Grey grades was established as

$$\boldsymbol{Y} = [0.514 \quad 0.833 \quad 0.784 \quad 0.500 \quad 0.489 \quad 0.482 \quad 0.500 \quad 0.411 \quad 0.397 \quad 0.394 \quad 0.400 \quad 0.399].$$

The data matrix $\boldsymbol{Y}$ was split into three clusters using SPSS. The three clusters—{P2, P3}, {P1, P4, P7, P5, P6} and {P8, P10, P9, P12, P11}—stand for the most important, important, and not important policy portfolios, respectively, in terms of developing Taiwan's SIP Mall industry (Fig. 14). Here, scientific and technical (P2) and education (P3) are the most important policy tools, while public enterprise (P1), information (P4), legal and regulatory (P7), financial (P5) and taxation (P6) also are important policy portfolios needed to develop Taiwan's SIP Mall industry. Other policy tools—including political (P8), public services (P10), commercial (P11), and overseas agent (P12), and procurement (P9)—are classified as less important policy tools.

Table 2
Symbols being used for representing the IIRs

Symbol	Contents
IIR1	e-Commerce capability
IIR2	Market leadership and customer education
IIR3	Time to market capability
IIR4	SIP sourcing capability
IIR5	SIP integration service capability
IIR6	SIP qualification capability
IIR7	SIP verification capability
IIR8	MPW services
IIR9	Legal protections
IIR10	Funding capability
IIR11	SIP know-how establishment
IIR12	Electronic systems know-how establishment
IIR13	Joint development capability
IIR14	SIP porting capability
IIR15	Strategic alliance capability
IIR16	Close relationship with foundries
IIR17	Close relationship with design service companies
IIR18	Close relationship with customers
IIR19	Close relationship with SIP providers
IIR20	Marketing capability
IIR21	Design service capabilities
IIR22	SIP safeguard techniques
IIR23	Knowledge management capability
IIR24	Human resources management capability

$$G=\begin{array}{ccccccccccc}
\text{IIR8} & \text{IIR9} & \text{IIR11} & \text{IIR12} & \text{IIR15} & \text{IIR16} & \text{IIR20} & \text{IIR22} & \text{IIR22} & \text{IIR24} & \\
3.333 & 3.833 & 3.833 & 4.167 & 3.833 & 3.333 & 3.333 & 3.333 & 3.167 & 2.833 & \text{P1}\\
7.167 & 3.833 & 6.500 & 7.333 & 4.500 & 3.833 & 5.167 & 6.667 & 5.000 & 3.833 & \text{P2}\\
5.667 & 6.167 & 5.000 & 5.500 & 3.167 & 3.667 & 4.500 & 7.333 & 6.667 & 7.833 & \text{P3}\\
1.833 & 4.333 & 3.500 & 4.000 & 3.833 & 1.833 & 4.833 & 2.167 & 3.333 & 2.500 & \text{P4}\\
6.000 & 1.500 & 2.333 & 1.833 & 2.167 & 2.000 & 2.167 & 3.500 & 4.167 & 7.167 & \text{P5}\\
5.500 & 1.500 & 2.167 & 1.667 & 2.167 & 2.167 & 2.000 & 3.500 & 4.333 & 7.167 & \text{P6}\\
1.333 & 7.667 & 2.333 & 1.667 & 4.000 & 2.333 & 2.000 & 2.333 & 2.333 & 4.333 & \text{P7}\\
1.333 & 5.667 & 2.000 & 1.667 & 1.667 & 2.000 & 2.000 & 2.000 & 2.167 & 4.167 & \text{P8}\\
2.833 & 3.000 & 2.333 & 2.500 & 2.333 & 2.000 & 1.833 & 2.167 & 2.167 & 2.000 & \text{P9}\\
2.000 & 2.667 & 2.167 & 2.833 & 2.000 & 2.000 & 2.167 & 2.167 & 2.667 & 2.000 & \text{P10}\\
1.667 & 2.500 & 2.000 & 2.167 & 3.167 & 2.000 & 2.000 & 2.167 & 2.000 & 2.333 & \text{P11}\\
1.833 & 2.000 & 1.667 & 1.833 & 2.833 & 1.500 & 2.333 & 2.167 & 1.833 & 4.667 & \text{P12}
\end{array}$$

Fig. 12. The initial relationship matrix ***G***.

Table 3
Symbols being used for representing the policy tools

Symbol	Contents	Symbol	Contents
P1	Public enterprise	P7	Legal and regulatory
P2	Scientific and technical	P8	Political
P3	Education	P9	Procurement
P4	Information	P10	Public services
P5	Financial	P11	Commercial
P6	Taxation	P12	Overseas agent

$$\boldsymbol{X}=\begin{bmatrix}
0.465 & 0.500 & 0.590 & 0.568 & 0.852 & 0.870 & 0.645 & 0.455 & 0.475 & 0.362\\
1.000 & 0.500 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 0.909 & 0.750 & 0.489\\
0.791 & 0.804 & 0.769 & 0.750 & 0.704 & 0.957 & 0.871 & 1.000 & 1.000 & 1.000\\
0.256 & 0.565 & 0.539 & 0.546 & 0.852 & 0.478 & 0.935 & 0.296 & 0.500 & 0.319\\
0.837 & 0.196 & 0.359 & 0.250 & 0.482 & 0.522 & 0.419 & 0.477 & 0.625 & 0.915\\
0.767 & 0.196 & 0.333 & 0.227 & 0.482 & 0.565 & 0.387 & 0.477 & 0.650 & 0.915\\
0.186 & 1.000 & 0.359 & 0.227 & 0.889 & 0.609 & 0.387 & 0.318 & 0.350 & 0.553\\
0.186 & 0.739 & 0.308 & 0.227 & 0.370 & 0.522 & 0.387 & 0.273 & 0.325 & 0.532\\
0.395 & 0.391 & 0.359 & 0.341 & 0.518 & 0.522 & 0.355 & 0.296 & 0.325 & 0.255\\
0.279 & 0.348 & 0.333 & 0.386 & 0.444 & 0.522 & 0.419 & 0.296 & 0.400 & 0.255\\
0.233 & 0.326 & 0.308 & 0.296 & 0.704 & 0.522 & 0.387 & 0.296 & 0.300 & 0.298\\
0.256 & 0.261 & 0.257 & 0.250 & 0.630 & 0.391 & 0.452 & 0.296 & 0.275 & 0.596
\end{bmatrix}$$

Fig. 13. The normalized correlation matrix ***X***.

Table 4
The grades of Grey relation with respect to innovation policy tools ($\zeta = 0.5$)

Innovation policy tool	Grade	Innovation policy tool	Grade
Public enterprise	0.514	Legal and regulatory	0.500
Scientific and technical	0.833	Political	0.411
Education	0.784	Procurement	0.397
Information	0.500	Public services	0.394
Financial	0.489	Commercial	0.400
Taxation	0.482	Overseas agent	0.399

6. Discussion

Despite conceptual advances, econometric models, and illustrative case studies, there are no straightforward answers to the questions: what elements should an innovation policy include, and how should such policies be implemented (Salmenkaita and Salo, 2002)? Examples of defining innovation policy elements with traditional qualitative approaches include the national innovation policy proposal for Cyprus by Hadjimanolis and Dickson (2001), the innovation policy proposal for developing Taiwan's competitive advantage by Shyu and Chiu (2002), and the reconfiguration of national innovation systems for German biotechnology by Kaiser and Prange (2004). Although popular, traditional qualitative approaches could be subjective and misleading. Meanwhile, collected information based on the assumption of independence between the various innovation requirements could be time wasting during the analysis procedure. Moreover, the vague correlations between innovation requirements and policy tools, and the lack of priorities of the policy tools deducted from the analysis procedure could cause governments to waste resources, merely because either low or no-priority policy instruments are executed.

In this paper, we demonstrated that an analytical approach can identify the complex relationships that exist between the various IIRs, and can clearly define the correlations between IIRs and innovation policy tools, thereby ranking policy priorities. DEMATEL served as an efficient tool to deduct the cause and effect relationships within an MCDM problem structure, and to simplify the relationships between IIRs. Even though the IIRs being

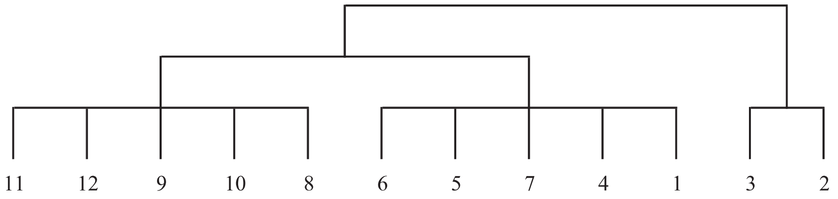

Fig. 14. Classification of the grades with respect to each policy tools by cluster analysis.

Table 5
The cause and effect relationships derived by DEMATEL

Effect	Causes	Cause and effect relationships and rationale
IIR1	IIR24	Human resources management (IIR24) affects the SIP Malls e-commerce capability
IIR2	IIR1, 6, 7, 8, 10, 11, 14, 15, 19, 20, 24	e-Commerce capability, SIP technical capabilities (IIR 6-7), funding capability (IIR10), strategic alliance capabilities (IIR15), relationships with providers (IIR19), human resource management (IIR24), and etc. affect market leadership and customer education
IIR3	IIR4, 5, 7, 11, 19, 24	SIP technical capabilities (IIR 4, 5, and 7), SIP know-how establishment (IIR11), relationships with providers (IIR19), and human resource management (IIR24) affect time to market capability
IIR4	IIR24	Human resources management (IIR24) affects SIP sourcing capability
IIR5	IIR11, 24	SIP know-how establishment (IIR11) and human resource management (IIR24) affects SIP integration service capability
IIR6	IIR24	Human resources management (IIR24) affects SIP qualification capability
IIR7	IIR24	Human resources management (IIR24) affects SIP verification capability
IIR10	IIR 7, 24	SIP verification capabilities (IIR7) and human resources management (IIR24) affect funding capability
IIR13	IIR24	Human resources management (IIR24) affects joint development capability
IIR14	IIR24	Human resource management (IIR24) affects SIP porting capability
IIR17	IIR24	Human resource management (IIR24) affects close relationship with design service companies
IIR18	IIR24	Human resources (IIR24) is the major factor affecting the relationship with customers (IIR18)
IIR19	IIR 11, 24	SIP know-how establishment and human resources management are major factors affecting the relationship with SIP providers
IIR21	IIR24	Human resources (IIR24) is the major factor affecting SIP Mall's design service capability

Remark: Threshold value = 0.100.

deducted by DEMATEL in Section 5.2—e-Commerce capability (IIR1); market leadership and customer education (IIR2); time-to-market capability (IIR3); SIP sourcing capability (IIR4); funding capability (IIR10); joint development capability (IIR13); SIP porting capability (IIR14); strategic alliance capability (IIR15); close relationships with customers (IIR18); close relationships with SIP providers (IIR19); and design service capabilities (IIR21)—were recognized by the experts as essential to enabling industrial innovation, the IIRs were classified as to the effects of major IIRs. The threshold value was set at 0.100, which covers 69 relationships, which comprise approximately 12% of the total 576 (24 × 24) relationships. If the threshold value was set higher than 0.100, the number of relationships to be analyzed could be too few to be representative; some IIRs would not be included in the total relationship. On the other hand, if the threshold value was set at a lower threshold value, the relationship number would be too huge to be analyzed. Thus, based upon a threshold value of 0.100, the relationships between IIRs—classified as major IIRs in the cause group and other IIRs in the effect group, as well as those either deducted or neglected in the GRA procedures—are listed below in Table 5. Table 5 shows both the clear cause-and-effect relationships and the rationales behind these relationships, demonstrating that every IIR deducted by DEMATEL already has been impacted by one or more major IIR(s).

For multiple criteria decision-making (MCDM) problems, GRA has advantages over traditional statistical correlation analysis. GRA is not constrained by sample numbers, whereas the total number of samples should be over 30 for traditional statistical relational analysis. Meanwhile, the weights for criteria can be introduced while calculating the grade in GRA (however, to facilitate the survey, we assumed that the weights of each criterion are equal.) Moreover, GRA derives the grade of Grey relation between criteria (IIR) and alternatives (innovation policy instruments), whereas statistical relational analysis derives the pair-wise correlation coefficients only. Finally, with GRA, the concepts of minimum and maximum are introduced, and the reference point is set for calculating the grades, specifically the distances between the variable and the reference point, while statistical correlation analysis calculates the sum of the products of two standardized values ($z_i = (x_{ij} - \bar{x}_i)/s_i; i = 1, 2, \ldots, p$) only.

Apparently, GRA serves as an effective tool for analyzing the correlation between policy tools or strategies versus IIRs or any criteria that are necessary for evaluating policies or strategies, especially when available experts in some specific fields of emerging technologies are limited. Thus, this procedure provides a solution for addressing the need to define a policy portfolio with clear steps, and is more appropriate for real-world policy definition problems.

Even though the Taiwanese government executed several national projects and policies to support the development of SIP Malls in the national Si-Soft project, which was rolled out in 2002, human resources management capability, knowledge management capability, SIP porting capability, MPW services, SIP know-how establishment, marketing capability, SIP safeguard techniques, strategic alliance capability, SIP verification capability, electronic systems know-how establishment, close relationship with design service companies, legal protections, e-Commerce capability, close relationship with foundries, funding capability, and SIP sourcing capability remain factors needed for industrial innovation.

Thus, innovation policy recommendations for developing Taiwan's SIP Mall industry, derived from analyzing the Grey relationships between IIRs and innovation policy tools, are discussed below.

Science and technical (P2) and education (P3) policy tools are classified as the most important tools. Science and technical policy tools (P2)—including research institutes like the Industrial Technology Research Institute (ITRI) and the National Chip Implementation Center (CIC) of Taiwan should serve as providers of expensive advanced-technology MPWs for SIP Mall and SIP vendors (IIR8). The research institutes also should enhance training in domain know-how of new SIP techniques (IIR11) and advanced electronic systems (IIR12). These tools can serve as 'bridge institutes' between SIP Malls and foundries and SIP providers (IIR15, 16) for strategic alliances. ITRI also should define the national SIP roadmap, and develop SIP safeguard techniques (IIR22) and a SIP Mall knowledge management platform (IIR23) as references or transferable techniques for SIP Malls.

Universities (P3) should train more personnel and enhance courses in the above-noted fields, including MPW operation, SIP and electronic system know-how, safeguard techniques, high-technology marketing, and knowledge management, in order to generate the personnel to meet the future needs of SIP Mall operations.

Public enterprise (P1), chosen as an important policy tool, implies that the current status—wherein existing SIP Malls still are experimental projects, operated either by design service companies or by non-profit research institutes that are not efficient and cannot generate profit—is not acceptable. To spin off existing SIP Malls as individual companies at a time when SIP Malls still are not profitable, the government should participate in SIP Mall companies via direct investment. With such governmental backing, SIP Mall companies would be more capable of establishing relationships with leading foundries and forming strategic alliances with major SIP providers and IC industry leaders, as SIP Mall customers.

Meanwhile, the government should leverage its financial (P5) tools through continuous funding of the SIP Malls, and by providing low interest loans. Doing so will meet the requirements that SIP Malls purchase expensive advance processes, MPW blocks, or wafers for MPW services (IIR8) to aid in SIP verification and qualifications. It also would allow for SIP Mall employee salaries (IIR24) and EDA tool investments to be sufficient. Taxation holiday or tax incentives (P6) also are regarded to be important tools for MPW investments (IIR8) and sustaining high-technology human resources (IIR24).

Currently, SIP Malls usually define their SIP portfolios and roadmaps based upon the domain knowledge of the design service companies operating them. Research institutes (P2) like the SOC Technology Center (STC) of ITRI and information centers and advisory and consultancy services (P4), like the Taiwanese government-funded Market Intelligence Center (MIC) of the Institute for Information Industry and the Industrial Economics & Knowledge Center (IEK) of ITRI, can provide technology and market information needed for an SIP development roadmap and SIP pricing, thereby forming the basis of SIP marketing jobs (IIR20).

We also would suggest that the Taiwanese government protects SIP transactions online and continues its efforts in SIP protection through legislation (P7), especially in the related fields of SIP source codes, layout, and software transmission using the Internet, so as to enhance the legal protection of SIP transactions (IIR9) on the web.

Comparing the proposed innovation policy portfolio with the current innovation policy, it is apparent that the Taiwanese government should participate in SIP Mall companies via direct investment (P1) rather than through funding R&D projects only. Major scientific and technical institutes (P2), including ITRI and CIC, proactively should provide SIP management courses, human resources, and design and engineering services; they also should serve as one of the major technology sources, and as bridging institutes between SIP providers, system designers, fabless design houses, foundries, and so on. Meanwhile, the human resource supply and demand gap remains significant, even though the Si-Soft Project tried to close the human resource supply and demand gap by using universities as a resource (P3). STC, IEK, and MIC should proactively provide technical, alliance, and free marketing information (P4) to new SIP Malls, which cannot afford expensive information services. Finally, the government's continuous funding (P5), tax allowances (P6), protecting SIP transactions online and continuous efforts in SIP protection (P7) also are necessary (see Table 6).

7. Conclusions

Despite the fact that SIP Malls play an important role in future SIP industry development, existing SIP Malls have not

Table 6
Differences between current and proposed innovation policy tools for Taiwan's SIP Mall industry

Classification	Current innovation policy	Proposed innovation policy	Differences
Supply side			
Public enterprise (P1)	● None	● Government investing SIP Malls directly	● Government investing SIP Malls directly
Scientific and technical (P2)	● Phase I of the National Si-Soft Project ○ Platform and SIP development ● ITRI(*) ○ SIP qualification standard definition	● ITRI(*) and CIC(*) serving as ○ Technology and service provider ○ SOC and SIP management training ○ Human resources provider ○ Bridging institutes	● ITRI(*) and CIC(*) serving as ○ Technology and service provider ○ SOC and SIP management training ○ Human resources provider ○ Bridging institutes
Education (P3)	● Phase I of the National Si-Soft Project ○ Human resources supply expansion ○ VLSI and system design education improvement ● CIC(*) providing ○ MPW services provider	● Universities expanding ○ Human resources supply in (a) Engineering (b) Management	● Human resources supply and demand gap still significant
Information (P4)	● IEK(*) and MIC(*) providing ○ Charged marketing information	● IEK(*), STC(*), and MIC(*) providing ○ Technical information ○ Strategic alliance information ● Marketing information	● STC(*) providing ○ Technical information ● IEK(*) and MIC(*) providing ○ Strategic alliance information ○ Free marketing information
Environmental side			
Financial (P5)	● Phase I of the National Si-Soft Project ○ SIP Mall infrastructure establishment ○ MPWs for SIP verifications	● Government's funding necessary for ○ E-commerce equipment purchasing ○ SIP technical capability ○ Strategic alliances ○ SIP purchasing	● Government continuously funding ○ E-commerce equipment purchasing ○ SIP technical capability ○ Strategic alliances ○ SIP purchasing
Taxation (P6)	● Tax allowances	● Company tax allowances ● Personal tax allowances	● Continuing tax allowances
Legal and regulatory (P7)	● Intellectual Property Protection Act ● Integrated Circuit Layout Protection Act ● Trade secret law	● Protecting SIP transactions online ● Continuing IP protection efforts	● Protecting SIP transactions online ● Continuing IP protection efforts

Remark: (1) ITRI: Industrial Technology Research Institute.
(2) CIC: National Chip Implementation Center.
(3) IEK: Industrial Economics & Knowledge Center.
(4) MIC: Market Intelligence Center.
(5) MOEA: Ministry of Economic Affairs.
(6) NSC: National Science Council.
(7) STC: SOC Technology Center.

achieved significant market shares. Based upon the research presented here, reconfiguration of the innovation policy portfolio to develop the SIP Mall industry is recommended, based upon IIRs derived using Delphi, and reduced by DEMATEL. The resulting portfolio was derived by mapping reduced IIRs to innovation policy tools by GRA, and then clustering these tools by Grey grades. Finally, empirical analysis based on Taiwan's SIP Mall industry was used to illustrate the analytical procedures.

The authors found that both scientific and technical, and education tools are the most important instruments, while public enterprise, information, financial, taxation, and legal and regulatory tools also are important in developing Taiwan's SIP Mall industry.

Research labs, including ITRI and CIC, should be involved heavily in providing services and technology for MPW services, domain know-how establishment, strategic alliance partner introduction, product marketing, safeguard techniques, knowledge management platform, and training. Universities should enhance their courses in the above fields and provide on-the-job training courses for engineers in the SIP and SIP Mall industries. Taiwan's government should invest in SIP Malls directly to solve current inefficiencies and to guarantee relationships with industry leaders and providers. Financial tools, including direct investment by government into SIP Mall companies, continuous funding of the SIP Malls, the provision of low interest loans, and taxation approaches that include tax holidays and/or tax incentives in the early stages of industry development, should be applied immediately. Doing so will help to develop the SIP Mall industry. Finally, the safety of SIP transactions through the Internet should be protected by legislation.

Finally, the analytical framework presented in this research can be applied both to the SIP Mall industry in other countries, and to other industries for evaluating policies or strategies.

Acknowledgements

The authors would like to express their sincere appreciation to the editor and reviewers for their helpful comments and suggestions.

Appendix A. Calculation of the total relationship matrix *T* in DEMATEL

The detailed process for calculating the total relationship matrix *T* in DEMATEL is illustrated below.

$$\begin{aligned}\boldsymbol{T} &= \boldsymbol{N}+\boldsymbol{N}^2+\ldots+\boldsymbol{N}^k\\ &= \boldsymbol{N}(\boldsymbol{I}+\boldsymbol{N}^2+\ldots+\boldsymbol{N}^{k-1})\\ &= \boldsymbol{N}(\boldsymbol{I}-\boldsymbol{N})^{-1}(\boldsymbol{I}-\boldsymbol{N})(\boldsymbol{I}+\boldsymbol{N}^2+\ldots+\boldsymbol{N}^{k-1})\\ &= \boldsymbol{N}(\boldsymbol{I}-\boldsymbol{N})^{-1}(\boldsymbol{I}-\boldsymbol{N}^k)\end{aligned}$$

Since $\lim\limits_{k\to\infty}\boldsymbol{N}^k=[\boldsymbol{0}]$, $\boldsymbol{T}=\boldsymbol{N}(\boldsymbol{I}-\boldsymbol{N})^{-1}$.

Appendix B. Explanation of the Grey relation coefficient calculations

Explanations for the mathematical equation used to calculate the Grey relation coefficient are as follows:

$$\gamma(x_0(k),x_i(k)) = \frac{\underset{\forall i}{\min}\,\underset{\forall k}{\min}\,|(x_0(k)-x_i(k))| + \zeta\,\underset{\forall i}{\max}\,\underset{\forall k}{\max}\,|(x_0(k)-x_i(k))|}{|(x_0(k)-x_i(k))| + \zeta\,\underset{\forall i}{\max}\,\underset{\forall k}{\max}\,|(x_0(k)-x_i(k))|},$$

where

$$X=\begin{bmatrix} x_0(1) & \cdots & x_0(k) & \cdots & x_0(n)\\ \vdots & \ddots & \vdots & \ddots & \vdots\\ x_i(1) & \cdots & x_i(k) & \cdots & x_i(n)\\ \vdots & \ddots & \vdots & \ddots & \vdots\\ x_m(1) & \cdots & x_m(k) & \cdots & x_m(n)\end{bmatrix}.$$

The item $\underset{\forall i}{\min}\,\underset{\forall k}{\min}\,|(x_0(k)-x_i(k))|$ in the dividend stands for the minimum distance between any element k in the comparative sequence x_i and the referential sequence x_0. The item $\zeta\,\underset{\forall i}{\max}\,\underset{\forall k}{\max}\,|(x_0(k)-x_i(k))|$ in both the dividend and the divisor serves as the background value used to guarantee that the Grey relation coefficient is in the range of 0–1. Consequently, when calculating the Grey relation coefficients for any element k in the comparative sequence x_i, the only item, which will be changed is $|(x_0(k)-x_i(k))|$, which stands for the distance between the sequence x_i and the sequence x_0. If the value of $|(x_0(k)-x_i(k))|$ increases, the grey relation coefficient $\gamma(x_0(k),x_i(k))$ decreases. On the other hand, if the value of $|(x_0(k)-x_i(k))|$ decreases, the Grey relation coefficient $\gamma(x_0(k),x_i(k))$ increases.

The symbol ζ stands for the distinguished coefficient ($\zeta\in[0,1]$). Generally, we pick $\zeta=0.5$. The scale of the Grey relation coefficients may be changed if we change the distinguished coefficient η. On one hand, if the distinguished coefficient is changed to '1' ($\eta=1$), the scale of the Grey relation coefficient will be a smaller number. On the other hand, if the distinguished coefficient is changed to '0' ($\eta=0$), the scale of the Grey relation coefficient will be a larger number versus when the scale of the Grey relation coefficient $\eta=0.5$. However, the sequence of the coefficients will not change even if we change the distinguished coefficient. For example, if $\gamma(x_0(k),x_i(k))$ is greater (or smaller) than $\gamma(x_0(k),x_j(k))$, the relationship remains unaltered if we change the value of the distinguished coefficient η. Therefore, by changing the distinguished coefficient, the Grey scales or Grey relationships will remain the same.

References

Adler, P.S., 2001. Market, hierarchy, and trust: the knowledge economy and the future of capitalism. Organization Science 12, 215–234.

Advisor Office of Ministry of Education, 2004. Introduction to VLSI circuits and Systems Education Program, 〈http://www2.ee.ntu.edu.tw/~vlsi/english/introduction.htm〉.

Afuah, A., 1998. Innovation Management: Strategies, Implementation, and Profits. Oxford University Press, New York.

Barthe's, J.-P.A., Tacla, C.A., 2002. Agent-supported portals and knowledge management in complex R&D projects. Computers in Industry 48.

Bekkers, R., Duysters, G., Verspagen, B., 2002. Intellectual property rights, strategic technology agreements and market structure—the case of GSM. Research Policy 31, 1141–1161.

Borg, E.A., 2001. Knowledge, information and intellectual property: implications for marketing relationships. Technovation 21, 515–524.

Carayannis, E.G., Popescu, D., Sipp, C., Stewart, M., 2006. Technological learning for entrepreneurial development (TL4ED) in the knowledge economy (KE): case studies and lessons learned. Technovation 26, 419–443.

Chang, C.-Y., Trappey, C.V., 2003. The national Si-Soft project. Applied Surface Science 216, 2–7.

Chiou, H.-K., Tzeng, G.-H., 2001. Fuzzy hierarchical evaluation with Grey Relation Model of green engineering for industry. International Journal of Fuzzy System 3, 466–475.

Chiu, Y.-J., Chen, H.-C., Tzeng, G.-H., Shyu, J.Z., 2006. Marketing strategy based on customer behaviour for the LCD-TV. International Journal of Management and Decision Making 7, 143–165.

Dalkey, N., Helmer, O., 1963. An experimental application of the Delphi method to the use of experts. Management Science 9, 458–467.

Deng, J.L., 1982. Control problems of Grey systems. Systems and Control Letters 5, 288–294.

Deng, J.L., 1985. Fundamental Methods of Grey Systems. Huazhoug University of Science and Technology, Wuhan, China.

Deng, J.L., 1986. Grey Forecasting and Decision. Huazhong University of Science and Technology Press, Wuhan.

Deng, J.L., 1988. Grey System Book. Science and Technology Information Services, Windsor.

Deng, J.L., 1989. Introduction of Grey theory. The Journal of Grey System 1, 1–24.

Dennis, R., Flavin, P., Davies, G., 1998. Online R&D management: the way forward. R&D Management 28, 27–35.

Design and Reuse, 2006. Short Facts About D&R, <http://www.us.design-reuse.com/about/>.

Edquist, C., 2001. Innovation policy—a systemic approach. In: Archibugi, D., Lundvall, B.A. (Eds.), The Globalizing Learning Economy. Oxford University Press, Oxford.

Edquist, C., Hommen, L., 1999. Systems of innovation: theory and policy for the demand side. Technology in Society 21, 63–79.

Everitt, B.S., Landau, S., Leese, M., 2001. Cluster Analysis. Arnold, London.

Florida, R., Kenney, M., 1991. The new age of capitalism. Futures 25, 637.

Freeman, C., 1982. The Economics of Industrial Innovation. The MIT Press, Cambridge, MA.

Gabus, A., Fontela, E., 1972. World Problems, An Invitation to Further Thought Within the Framework of DEMATEL. Battelle Geneva Research Center, Geneva, Switzerland.

Gajski, D.D., Wu, A.C.H., Chaiyakul, V., Mori, S., Nukiyama, T., Bricaud, P., 2000. Essential issues for IP reuse. In: Proceedings of the ASP-DAC 2000, pp. 37–52.

Goering, R., 2003. Virtual Component Exchange becomes private company, <http://www.eetimes.com/news/design/showArticle.jhtml;jsessionid=PKWXG1G2IWB52QSNDBECKHSCJUMEKJVN?articleID=17408643>.

Hadjimanolis, A., Dickson, K., 2001. Development of national innovation policy in small developing countries: the case of Cyprus. Research Policy 30, 805–817.

Hori, S., Shimizu, Y., 1999. Designing methods of human interface for supervisory control systems. Control Engineering Practice 7, 1413–1419.

Hung, S.-C., Chu, Y.-Y., 2006. Stimulating new industries from emerging technologies: challenges for the public sector. Technovation 26, 104–110.

IPTC, 2004. About IPTC, <http://www2.iptc.com/eopen/index.html>.

Jones, J., Hunter, D., 1995. Qualitative research: consensus methods for medical and health services research. British Medical Journal 311, 376–380.

Kachigan, S.K., 1991. Multivariate Statistical Analysis: A Conceptual Introduction. Radius Press, New York.

Kaiser, R., Prange, H., 2004. The reconfiguration of national innovation systems—the example of German biotechnology. Research Policy 33, 395–408.

Kerssens-Van, D.I., Weerd-Nederhof, P., Fisscher, O., 1996. Describing the issues of knowledge management in R&D: towards a communication and analysis tool. R&D Management 26, 213–230.

Linstone, H.A., Turoff, M., 1975. The Delphi Method: Techniques and Applications. Addison-Wesley, London.

Mon, D.L., Tzeng, G.H., Lu, H.C., 1995. Grey decision making in weapon system evaluation. Journal of Chung Chen Institute of Technology 26, 73–84.

Moore, G., 1979. VLSI: some fundamental challenges. IEEE Spectrum 16, 30–37.

Mowery, D., 1995. The practice of technology policy. In: Stoneman, P. (Ed.), Handbook of the Economics of Innovation and Technological Change. Blackwell Publishers Inc., Cambridge, MA, pp. 513–557.

Nieto, M., 2002. From R&D management to knowledge management: an overview of studies on innovation management. Technological Forecasting and Social Change 70, 135–161.

Park, Y., Kim, S., 2004. Knowledge management system for fourth generation R&D: Knowvation. Technovation 26, 595–602.

Perlman, M., Heertje, A., 1991. Evolving Technology and Market Structure: Studies in Schumpeterian Economics. University of Michigan Press, Michigan.

Rappert, B., Webster, A., 1997. Regimes of ordering: the commercialisation of intellectual property in industrial-academic collaborations. Technology Analysis and Strategic Management 9, 115–130.

Ratford, V., Popper, N., Caldwell, D., Katsioulas, T., 2003. Understanding the Semiconductor Intellectual Property (SIP) Business Process. Fabless Semiconductor Association, Texas.

Rothwell, R., Zegveld, W., 1982. Industrial Innovation and Public Policy: Preparing for the 1980s and the 1990s. Printer, London.

Salmenkaita, J.P., Salo, A., 2002. Rationales for government intervention in the commercialization of new technologies. Technology Analysis & Strategic Management 14, 183–200.

Semiconductor Industry Association, 2002. International Technology Roadmap for Semiconductors 2002 Edition. Semiconductor Industry Association, Austin.

Sharma, S., 1996. Applied Multivariate Techniques. Wiley, New York.

Shyu, J.Z., 1999. Technology Policy and National Innovation System. Hwa-Tai Publication, Taiwan.

Shyu, J.Z., Chiu, Y.C., 2002. Innovation policy for developing Taiwan's competitive advantages. R&D Management 32, 369–374.

Sobrero, M., Roberts, E.B., 2002. Strategic management of supplier—manufacturer relations in new product development. Research Policy 31, 159–182.

Sullivan, P., Harrison, S., Keeler, G., Villella, J., 2002. The Value and Management of Intellectual Assets. VSI Alliance, Inc., MA.

Sundbo, J., 2003. Innovation as Strategic Reflexivity. Taylor & Francis, New York.

Tamura, M., Nagata, H., Akazawa, K., 2002. Extraction and systems analysis of factors that prevent safety and security by structural models. In: Proceedings of the 41st SICE Annual Conference, vol. 3, Osaka, Japan, pp. 1752–1759.

Tidd, J., Brocklehurst, M., 1993. Innovation and collaboration: towards a new strategy for European business. European Business Journal 3, 87–105.

Tzeng, G.-H., 1978. Multivariate Analysis and its Applications. Hwa-Tai, Taipei, Taiwan.

Tzeng, G.H., Tasur, S.H., 1994. The multiple criteria evaluation of Grey relation model. The Journal of Grey System 6, 87–108.

VSIA, 2006. About VSIA, <http://www.vsi.org/aboutVSIA/index.htm>.

Williams, D., Chao, P.C., Wang, Y.C., Wu, C.S., 2002. Process porting provides a path to production scaling. Compound Semiconductor, 8.

Wonglimpiyarat, J., 2006. The dynamic economic engine at Silicon Valley and US Government programmes in financing innovations. Technovation 26, 1081–1089.

Worchel, G.S., 2004. Independent IP Logic Market: The Designers Foundation, and User Survey. Cahners In-Stat Group, Arizona.

Wu, H.S., Deng, J.L., Wen, K.L., 1996. Introduction of Grey Analysis. Gau-Li Publication Inc., Taiwan.

Yoo, H. J., 2003. The Semiconductor Intellectual Property—A New Driving Force, <http://www.sipac.org/About/Preface.jsp?1129827978746>.

Chi-Yo Huang received his B.S. degree in Electrical Engineering in 1990 from National Cheng-Kung University, Taiwan, his M.S. degree in Computer Engineering in 1993 from Syracuse University, New York, and his Ph.D. degree in Management of Technology in 2006 from National Chiao-Tung University, Taiwan. He worked in the IC industry for more than 11 years as IC design engineer, marketing manager and marketing director. His major responsibilities included PC chipset design, marketing strategy and product definition, technology transfer and new business development. Dr. Huang is now an assistant professor of the Department of Industrial Education, National Taiwan Normal University, Taiwan. His recent research interests include competitive strategies of high-technology firms, innovation policy analysis, e-Commerce and technological forecasting of high-tech products.

Joseph Z. Shyu received his B.S. degree in Chemistry from Fu-Jen Catholic University in 1976, his M.S. in Applied Chemistry from National Tsing-Hua University, Taiwan, in 1978 and his Ph.D. in Analytical Chemistry from University of Pittsburg, Pennsylvania, in 1982. He also received his MBA degree from Illinois Institute of Technology in 1992. After working in industry in the United States for over 10 years, he returned to Taiwan in 1993, holding a position of professor in Graduate Institute of Technology of Management in National Chiao Tung University, Taiwan. His recent research interests include National Innovation System (NIS), high-technology business strategy, and global marketing strategy.

Gwo-Hshiung Tzeng received his B.S. degree in business management in 1967 from the Tatung Institute of Technology, his M.S. degree in urban planning in 1971 from the Chung Hsing University, and his Ph.D. degree in management science in 1977 from Osaka University. He is now a professor of Institute of Management of Technology, National Chiao Tung University, Taiwan. Dr. Tzeng is a three-time recipient of the distinguished research award and is a distinguished research fellow (highest honor offered) of the National Science Council of Taiwan. He is a member of IAEE, ISMCDM, World Transport, the Operations Research Society of Japan, the Society of Instrument and Control Engineers Society of Japan, the City Planning Institute of Japan, the Behaviormetric Society of Japan, and Japan Society for Fuzzy Theory and Systems.