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Identification of interrelationship of key customers' needs based on structural model for services/capabilities provided by a Semiconductor-Intellectual-Property Mall

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A R T I C L E I N F O

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A B S T R A C T

The semiconductor industry is shifting towards innovation and acquisition of intellectual property. Semiconductor-Intellectual-Property (SIP) design, a new industry, is also rapidly growing. This challenges both providers and users to develop infrastructure and standard interfaces. Establishing an SIP Mall to provide a full array of SIP business services is a new concept used to promote growth of the SIP industry. Many foundries and governments have been involved in setting up SIP Malls; however, the major services needed for an SIP Mall to attract SIP providers and SIP users must still be clarified. In this paper, the DEMATEL (DEcision MAking Trial and Evaluation Laboratory) method was used to discover and illustrate the key services needed to attract SIP users and SIP providers to an SIP Mall. Research enabled the derivation of the interrelated services and the structural interrelationship between them using the DEMATEL method. Overall, four key services were found to be vital for an SIP Mall to attract customers and to allocate resources efficiently.

1. Introduction

SIPs are pre-designed functions that can be implemented in one or more semiconductor devices, such as Application Specific Integrated Circuits (ASICs), Application Specific Standard Products (ASSPs) or Programmable Logic Devices (PLDs). There are three types of SIPs: Soft SIPs, Hard SIPs and Firm SIPs. These SIP types are based on the degree to which an SIP has been targeted toward a particular fabrication process [1,2] SIP users choose which type of SIP to purchase by considering whether or not the SIPs meet the specific project requirements, availability, specifications, cost, number of sources, reputation of suppliers, and number of foundries supported [3]. Because of the competitive pressure, improved time-to-market, availability of deep-submicron manufacturing processes [4], trend of outsourcing, and booming of the System-On-a-Chip (SOC) era, the SIP market has grown faster than the semiconductor market overall [5,6].

The SIP Mall is a transaction platform for gathering SIPs and promoting SIP trade services. However, SIP users and SIP providers face many obstacles in the process of purchasing SIPs. Due to the increased use of commercial SIPs from multiple sources, the process of finding and evaluating SIPs has become time consuming and more complex. The primary concern for an SIP Mall is how to attract SIP providers and SIP users. While SIP Mall founders must determine which services are most conducive to operating an attractive SIP Mall, these issues have rarely been studied.

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In this paper, we interviewed chief-executive officers, senior technical personnel, and marketing managers to determine which services (customer's needs) were required for establishing a successful SIP Mall. Our hypothesis was analyzed by using the DEMATEL method [7]. Unlike a Structural Equation Model (SEM), which has been applied in a number of economic arenas to determine the structure of correlations between variables, the DEMATEL method illustrates the structure and interrelationships of the services and induces a few key services to improve its effectiveness. The DEMATEL method determines 18 influential services and their interrelationships.

The rest of this paper is organized as follows: Section 2 describes the issues of the emerging SIP Mall. In Section 3, we describe the DEMATEL method, explain how to construct the data set of this study, and illustrate the interrelationships of these 18 services. The roles of the 18 services for establishing an attractive SIP Mall, which were analyzed by the DEMATEL method, are discussed in Section 4. Finally, in Section 5, we draw conclusions and offer some discussion related to future work.

2. Issues of an SIP Mall

The SIP Mall is designed to provide the services needed for SIP providers and SIP users to reduce the time, risk and cost of chip design, and to allow chip design companies to have sufficient and reliable key components for marching into the worldwide chip design market. Although the functions of the SIP Mall are helpful for customers and could accelerate the growth of the SIP market, there are still some obstacles for the development of the SIP Mall.

In the process of chip design, from clarifying the functional specifications of the requirements to verifying the functions of the chips, it is found to be difficult for designers to incorporate SIPs into a single design because companies have different SIP design specification requirements. SIP providers and users meet with difficult integration situations in the trading environment. Legal provisions [8,9], application platform development, SIP development, and other services related to the trading procedure [10] should also be considered before SIP trading. Significant Internet-related obstacles, including SIP ownership conflicts, design support disputes that reflect interdependencies among individual design blocks, and disagreements over pricing and royalties [11] also should be considered. Currently, most contracts are negotiated, signed and completed only between the licensor and the licensee. A design that incorporates multiple SIP products may involve several SIP providers and more than one source of manufacturing. As a result, SIP users have to manage multiple providers in the supply chain, each with different business models and technical capabilities. Even though the SIP business models tend to be more complex, an intermediary, or agent such as the SIP Mall, does not play a major role in the process. The situations make customers consider outsourcing jobs to an agent, but make them doubt that the SIP Mall can resolve these problems.

An important issue for an SIP Mall is how to attract SIP providers and SIP users to trade it. In addition to feasibility and efficiency, the founders of SIP Malls have to know the perceptions, relationships and needs of both SIP providers and SIP users [12–14] and differentiate their services from the consortium and other SIP vendors. To address this issue, it is necessary to answer the following questions: What critical services should an SIP Mall provide? Do these services all have the same priorities? Is there any interrelation between them? How should an SIP Mall perform these services? To truly benefit its customers, an SIP Mall must understand the needs and expectations of all parties related to the SIP Mall. Answering these questions is also critical to the SIP industry to clarify the role of the SIP agent. In the next section, we will describe the DEMATEL method, explain how to construct the research data set of this study, and illustrate the analysis results.

3. DEMATEL method and interrelated factors

The DEMATEL method is based upon graph theory, enabling us to plan and solve problems visually, so that we may divide the factors into a cause and effect group, in order to better understand causal relationships. The purpose of the DEMATEL enquiry in this paper, with experts' knowledge for contributing to a deeper comprehension of the component services, is the analysis of the structure and interrelationships of the services, and the identification of the key services which will influence the satisfaction of customers for an SIP Mall.

3.1. DEMATEL method

The DEMATEL method, developed by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva between 1972 and 1976, was used for researching and solving complicated and intertwined problem groups [15,16]. The methodology can confirm interdependence among variables and develop a chart that reflects interrelationships between variables. The end product of the DEMATEL process is a visual representation – an individual map of the mind – by which the respondent organizes his or her own action in the world. This organization process must occur for the respondent to keep internally coherent and to reach his personal goals. The applicability of the method is widespread, ranging from analyzing world problematique decision making to industrial planning [17–21]. The steps of the DEMATEL method are described as follows:

Step 1: Find the average matrix

Suppose there are H experts available to solve a complex problem and there are n factors to be considered (in this study, ten levels are adopted, as relations between the 18 factors). The scores by each expert give us a $n \times n$ non-negative answer matrix $\boldsymbol{X}^k$, with $1 \leqslant k \leqslant H$. Thus $\boldsymbol{X}^1, \boldsymbol{X}^2, \ldots, \boldsymbol{X}^H$ are the answer matrices for each of the H experts, and each element of $\boldsymbol{X}^k$ is an integer denoted by $\boldsymbol{x}_{ij}^k$. The diagonal elements of each answer matrix $\boldsymbol{X}^k$ are all set to zero. We can then compute the n x n average matrix $\boldsymbol{A}$ by averaging the H experts' scores matrices. The (i,j) element of matrix $\boldsymbol{A}$ is denoted by a_{ij},

$$a_{ij} = \frac{1}{H}\sum_{k=1}^{H} x_{ij}^k. \tag{1}$$

In application, respondents were asked to indicate the direct influence that they believe each factor exerts on each of the others according to an integer scale ranging from 0 to 4. A high score from a respondent indicates a belief that greater improvement in i is required to improve j. From any group of direct matrices of respondents it is possible to derive an average matrix $\boldsymbol{A}$.

Step 2: Calculate the Normalized Initial Direct-Relation matrix

We then create a matrix $\boldsymbol{D}$, by using a simple matrix operation on $\boldsymbol{A}$. Suppose we create matrix $\boldsymbol{D}$ and $\boldsymbol{D} = s \cdot A$ where

$$s = \text{Min}\left(\frac{1}{\max\limits_{1\leqslant i\leqslant n}\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{\max\limits_{1\leqslant j\leqslant n}\sum_{i=1}^{n}|a_{ij}|}\right). \tag{2}$$

Matrix $\boldsymbol{D}$ is called the *Normalized Initial Direct-Relation matrix*. The (i,j) element d_{ij} denotes the direct influence from factor x_i to factor x_j. Suppose d_i denotes the row sum of the ith row of matrix $\boldsymbol{D}$.

$$d_{i\cdot} = \sum_{j=1}^{n} d_{ij}, \tag{3}$$

The $d_{i\cdot}$ shows the sum of influence exerted from factor x_i to the other factors directly. Suppose $d_{\cdot j}$ denotes the column sum of the jth column of matrix $\boldsymbol{D}$.

$$d_{\cdot j} = \sum_{i=1}^{n} d_{ij}. \tag{4}$$

Then $d_{\cdot j}$ shows the sum of influence that factor x_j received from the other factors. We can normalize $d_{i\cdot}$ and $d_{\cdot j}$ as

$$w_i(d) = \frac{d_{i\cdot}}{\sum_{i=1}^{n} d_{i\cdot}}, \tag{5}$$

$$v_j(d) = \frac{d_{\cdot j}}{\sum_{j=1}^{n} d_{\cdot j}}. \tag{6}$$

Matrix $\boldsymbol{D}$ shows the initial influence which a factor exerts and receives from another (see Appendix A). Each element of matrix $\boldsymbol{D}$ portrays a contextual relationship among the elements of the system and can be converted into a visible structural model – an *impact-relations-map* – of the system with respect to that relationship. For example, as shown in Fig. 1, the respondents are requested to indicate only direct links. In the directed digraph graph represented in Fig. 1, factor i directly affects only factors j and k; indirectly, it also affects first l, m and n and, secondly, o and q. The digraph map helps to explain the structure of the factors.

Step 3: Compute the total relation matrix

The element $d_{ij}^{(2)}$ of $\boldsymbol{D}^2$ means that factor x_i exerts its direct/indirect influence on factor x_j ($j = 1, 2, \ldots, n$) through all factors during phase 2. The element $d_{ij}^{(m)}$ of $\boldsymbol{D}^m$ means that factor x_i exerts its influence on factor x_j ($j = 1, 2, \ldots, n$) through direct/

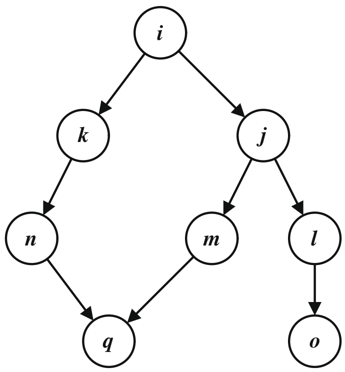


Fig. 1. Example of a direct graph.

indirect influence of all factors during phase m.A continuous decrease of the indirect effects of problems along the powers of matrix $\boldsymbol{D}$, e.g. $\boldsymbol{D}^2,\boldsymbol{D}^3,\ldots,\boldsymbol{D}^\infty$, guarantees convergent solutions to the matrix inversion, similar to an absorbing Markov chain matrix. Note that $\boldsymbol{D} = [d_{ij}]_{n\times n}$, $0 \leqslant d_{ij} < 1$, where $0 \leqslant \left\{\sum_{j=1}^{n} d_{ij} \text{ or } \sum_{i=1}^{n} d_{ij}\right\} < 1$, and at least one $\sum_{j=1}^{n} d_{ij}$ or $\sum_{i=1}^{n} d_{ij}$ equal to 1, $\forall i, j \in \{1, 2, \ldots, n\}$, then $\lim_{m\to\infty} \boldsymbol{D}^m = [\mathbf{0}]_{n\times n}$, where $[\mathbf{0}]_{n\times n}$ is the $n \times n$ null matrix. The total relation matrix $\boldsymbol{T}$ is an $n \times n$ matrix and is defined as follows:

$$\sum_{m=1}^{\infty} \boldsymbol{D}^i = \boldsymbol{D} + \boldsymbol{D}^2 + \boldsymbol{D}^3 + \cdots + \boldsymbol{D}^m = \boldsymbol{D}(\mathbf{I} + \boldsymbol{D} + \boldsymbol{D}^2 + \boldsymbol{D}^3 + \cdots + \boldsymbol{D}^{m-1})$$
$$= \boldsymbol{D}(\mathbf{I} - \boldsymbol{D})^{-1}(I - \boldsymbol{D})(\mathbf{I} + \boldsymbol{D} + \boldsymbol{D}^2 + \boldsymbol{D}^3 + \cdots + \boldsymbol{D}^{m-1}) = \boldsymbol{D}(\mathbf{I} - \boldsymbol{D})^{-1}(\mathbf{I} - \boldsymbol{D}^m) = \boldsymbol{D}(\mathbf{I} - \boldsymbol{D})^{-1}. \quad (7)$$

I is the identity matrix. ***T*** is called the *total relation matrix*. The (i,j) element of the matrix $\boldsymbol{T}$, t_{ij}, denotes the full direct and indirect influence exerted from factor x_i to factor x_j. Like the formula (3)–(6), we can obtain $t_{i\cdot}$, $t_{\cdot j}$, $w_i(t)$ and $v_j(t)$.

Step 4: *Set a threshold value and obtain the impact-relations-map*

In order to explain the structural relationship among the factors, while keeping the complexity of the system to a manageable level, it is necessary to set a threshold value p to filter out the negligible effects in matrix $\boldsymbol{T}$. Using the values of $w_i(t)$ and $v_i(t)$ from the matrix of full direct/indirect influence relations, the level of dispatching and receiving of the influence of factor i can be defined. The inter-relationship of each factor can be visualized as the oriented graphs on a two-dimensional plane after a certain threshold is set. Only those factors that have an effect in matrix $\boldsymbol{T}$ that is greater than the threshold value should be chosen and shown in an impact-relations-map.The threshold value is decided by

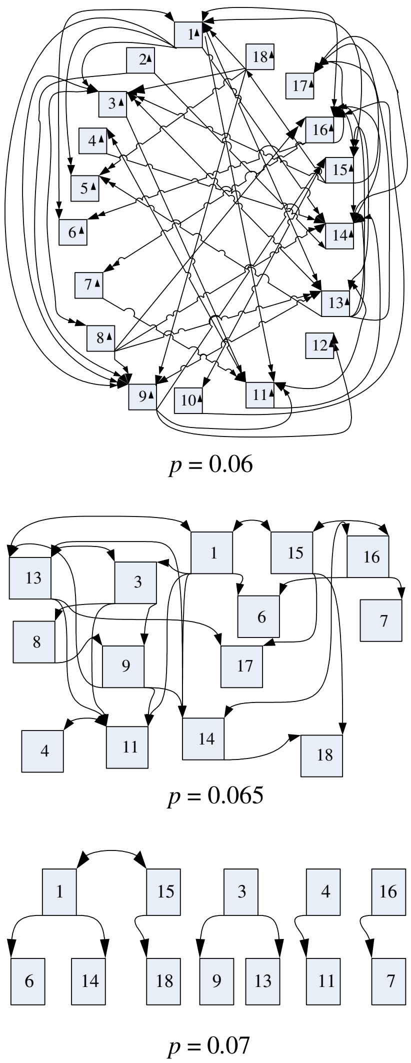


Fig. 2. Examples of a complex relationship graph based on different threshold values (data is taken from the Initial Direct-Influence Matrix, shown in Appendix B of this paper).

the decision maker or, in this study, by experts through discussion. If the threshold value is too low, the map will be too complex to show the necessary information for decision-making. If the threshold value is too high, many factors will be presented as independent factors, without showing relationships with the other factors. Each time the threshold value increases, some factors or relationships will be removed from the map (Examples are shown in Fig. 2.) An appropriate threshold value is necessary to obtain a suitable impact-relations-map and adequate information for further analysis and decision-making.Furthermore, after a suitable map is obtained, the focus of the problem can be shown by analyzing the values w_i and v_i of the factors in the map. The value $(w_i + v_i)$ – the index representing the strength of the influence both dispatched and received – shows the degree of the central role that the factor i plays in the problem. Commonly, a higher $(w_i + v_i)$ value means that the factor has a stronger connection with the other factors and plays a central role. The value $(w_i - v_i)$ is another index representing the role of a factor. A higher $(w_i - v_i)$ value means that it has a stronger influence *on* other factors, than the influence it *receives* from them. If $(w_i - v_i)$ is positive, then the factor i is dispatching influence to the other factors. If $(w_i - v_i)$ is negative, then the factor i is receiving influence from the other factors. Different $(w_i + v_i)$ and $(w_i - v_i)$ values will be explained along with the structure of the factors' effects.

3.2. Data set

To conduct our research, a services list and questionnaire were created by consulting with academics and practitioners that focus on the SIP trading and licensing process. The services list and questionnaire take into account several dimensions of services, of which SIP providers and users need to be aware, such as technology, cost, strategy, and legal issues [22–27].

Second, based on listings in the "2003 Semiconductor Industry Yearbook" [28], companies were surveyed via phone and e-mail about their willingness to participate and their level of experience in the SIP trading and licensing process. There were 24 companies that agreed to answer the questionnaire and discuss their responses. These 24 companies were experienced as licensees and licensors in the SIP business and had extensive knowledge about SIP trading and licensing. After we discussed and revised the questionnaire with their chief executive officers, senior technical personnel, and marketing managers, 18 interrelated services (presented in Table 1) were included to use in the final questionnaire.

In our questionnaire, experts were to be asked to use the DEMATEL approach to measure the influence of each service on the others. The relationships among the 18 services were measured using a scale from 0 to 9 (where 0 is "no influence" and 9 is "the most influence"). Experts evaluated the relationship between sets of paired services in terms of degree of influence and direction of mutual movements. In total, 24 questionnaires were sent to experters, 19 questionnaires were responded. Because of missing data, the final sample size for this study became 17, constituting an effective response rate of 71%. The response data, an 18 × 18 scoring matrix, for each company, was used for the DEMATEL analysis. Then, a Total Relation Matrix was obtained from the 17 18 × 18 weighted matrices. Finally, based on the Total Relation Matrix and experts' advice, a threshold value was determined and a graphical presentation, referred to as an impact-relations-map, of the interrelationships among the services was created and discussed.

4. Results

4.1. The normalized Initial Direct-Influence Matrix

After receiving the 17 questionnaire responses, an average matrix $\boldsymbol{A}$ (an 18 × 18 matrix) was calculated and a Normalized Initial Direct-Influence Matrix $\boldsymbol{D}$, shown in Appendix A, was derived.

Table 1
The 18 services identified as necessary to have a successful SIP Mall.

Services	Notation
Verification	x_1
Financial assistance	x_2
Research institutions Questing	x_3
Credit investigation	x_4
Business process streamlining	x_5
SIP support and maintenance	x_6
Increasing company awareness	x_7
Patent analysis	x_8
Technology valuation	x_9
Establishing strategic partnership	x_{10}
Licensing support	x_{11}
Project assessment	x_{12}
SIP grading	x_{13}
Better price negotiation	x_{14}
Technical standard specifying	x_{15}
Market share improving	x_{16}
Overhead cost saving	x_{17}
Documentation	x_{18}

4.2. The total relation matrix

After deriving the Total Relation Matrix $\boldsymbol{T}$, based on the Normalized Initial Direct-Influence Matrix $\boldsymbol{D}$, the values w_i and v_i of each service can be mapped to a coordinate plane, as shown in Fig. 3. The points above the diagonal, ($w_i > v_i$), indicate that the services exerted more influence than they received, and vice versa.

Ten services which exerted more influence than they received are located above the diagonal and the "SIP Grading (x_{13})" service and have the highest w_i values (0.065). This provides a clue for the following analysis that the services which affect service "SIP Grading" may play central roles in the problem. Eight services are under the diagonal, and the service "Better Price Negotiation (x_{14})" has the highest v_i value (0.0643). This provides a clue that the "Better Price Negotiation" service might be on the lowest level of the structured map, if the "Better Price Negotiation" service is included in the map.

4.3. Threshold values and the impact-relations-map

Based on the matrix $\boldsymbol{T}$, the maximum threshold value that allowed all services to be displayed on the impact-relations-map was 0.36. When the threshold value increased to 0.45, only two direct relationships existed: service "Verification" directly affected service "Better Price Negotiation" (0.4587) and service "SIP Grading" directly affected service "Better Price Negotiation" (0.4612). After raising the threshold value from 0.36 to 0.45 in increments of 0.01 and conferring with experts to determine the optimal value to sufficiently display the interrelationships among these services, the threshold value was decided to be 0.42. Thus, the structured impact-relations-map was also decided as shown in Fig. 4. There were nine services whose values of exerted or received influence were higher than 0.42. Fig. 4 illustrates the relationships among these nine services: "Verification", "Research Institutions Questing", "Technology Valuation", "Licensing Support", "SIP Grading", "Better Price Negotiation", "Technical Standard Specifying", "Market Share Improving" and "Overhead Cost Saving". Fig. 4 also shows that, because of their obvious interrelationships, these nine services are related to establishing or operating an attractive SIP Mall.

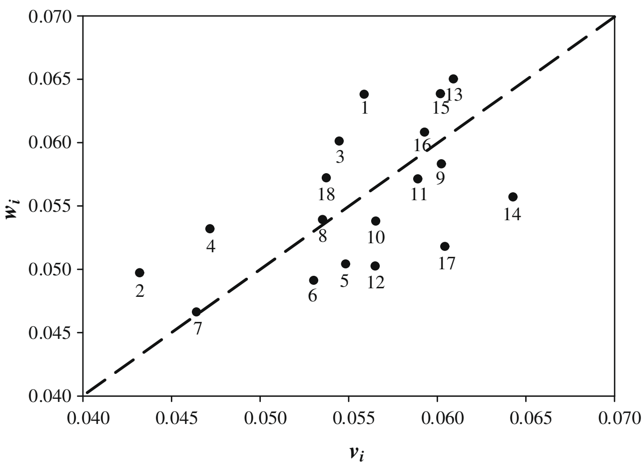
4.4. The ($w_i + v_i$) and ($w_i - v_i$) values of services

Based on Step 4 in Section 3, we obtained the values of ($w_i + v_i$) and ($w_i - v_i$) and their coordinate plane (see Fig. 5). Of the nine services shown in Fig. 4, the "SIP Grading (x_{13})" service had the highest ($w_i + v_i$) value (0.1259) in Fig. 5. The ($w_i + v_i$) value is an index for the DEMATEL method. The analysis of the impact-relations-map was started from service whose ($w_i + v_i$) is the highest, "SIP Grading (x_{13})".

The "Verification", "Research Institutions Questing", "SIP Grading" and "Technical Standard Specifying" services are the most important services for an SIP Mall. They exerted complete direct/indirect influence to five other services – "Technology Valuation", "Licensing Support", "Better Price Negotiation", "Market Share Improving" and "Overhead Cost Saving". If an SIP Mall wants to provide the "Technology Valuation", "Licensing Support", "Better Price Negotiation", "Market Share Improving" and "Overhead Cost Saving" services, it must first demonstrate to consumers the capabilities of "Verification", "SIP Grading" and "Technical Standard Specifying". The "Research Institutions Questing" capability is also needed to support the "SIP Grading" and "Technical Standard Specifying" capabilities.

4.5. The remaining services

Excluding the nine services displayed in Fig. 4, the remaining services were considered to be independent services for an SIP Mall. Although the "Project Assessment", "Better Price Negotiation" and "Overhead Cost Saving" services, with negative



	v_i	w_i	Capability/Service
x_1	0.0559	0.0638	Verification
x_2	0.0432	0.0497	Financial Assistance
x_3	0.0545	0.0601	Research Institutions Questing
x_4	0.0472	0.0531	Credit Investigation
x_5	0.0549	0.0504	Business Process Streamlining
x_6	0.0531	0.0491	SIP Support and Maintenance
x_7	0.0464	0.0466	Increasing Company Awareness
x_8	0.0536	0.0539	Patent Analysis
x_9	0.0603	0.0583	Technology Valuation
x_{10}	0.0566	0.0538	Establishing Strategic Partnership
x_{11}	0.0589	0.0571	Licensing Support
x_{12}	0.0565	0.0502	Project Assessment
x_{13}	0.0609	0.0650	SIP Grading
x_{14}	0.0643	0.0557	Better Price Negotiation
x_{15}	0.0602	0.0638	Technical Standard Specifying
x_{16}	0.0593	0.0608	Market Share Improving
x_{17}	0.0605	0.0518	Overhead Cost Saving
x_{18}	0.0538	0.0572	Documentation

Fig. 3. The values w_i and v_i of each service (the points above the diagonal indicate services which exerted more influence than they received ($w_i > v_i$)).

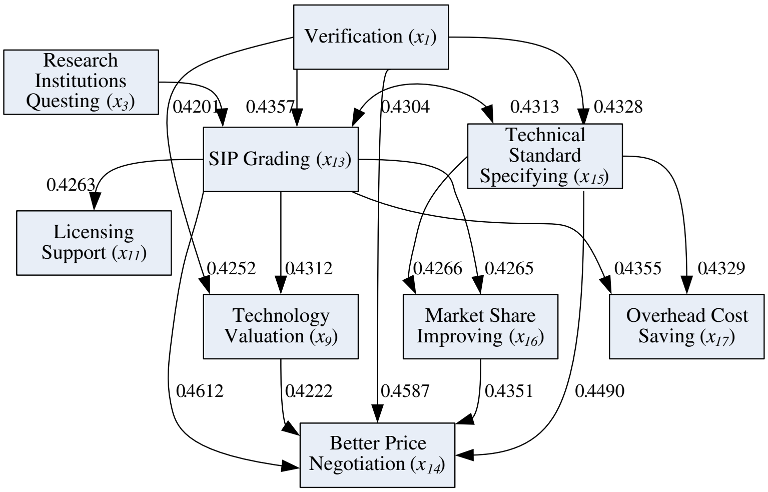
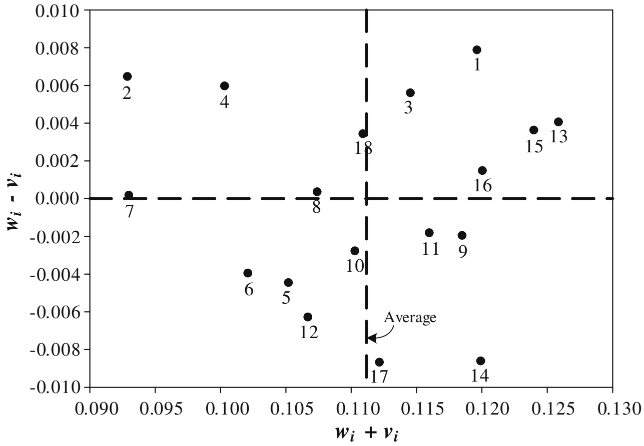


Fig. 4. Impact-relations-map based on the threshold value $p = 0.42$.



	$w_i + v_i$	$w_i - v_i$	Capability/Service
x_1	0.1197	0.0078	Verification
x_2	0.0929	0.0064	Financial Assistance
x_3	0.1146	0.0056	Research Institutions Questing
x_4	0.1004	0.0059	Credit Investigation
x_5	0.1052	-0.0045	Business Process Streamlining
x_6	0.1021	-0.0040	SIP Support and Maintenance
x_7	0.0930	0.0001	Increasing Company Awareness
x_8	0.1074	0.0003	Patent Analysis
x_9	0.1185	-0.0020	Technology Valuation
x_{10}	0.1103	-0.0028	Establishing Strategic Partnership
x_{11}	0.1160	-0.0018	Licensing Support
x_{12}	0.1067	-0.0063	Project Assessment
x_{13}	0.1259	0.0040	SIP Grading
x_{14}	0.1200	-0.0086	Better Price Negotiation
x_{15}	0.1240	0.0036	Technical Standard Specifying
x_{16}	0.1201	0.0015	Market Share Improving
x_{17}	0.1122	-0.0087	Overhead Cost Saving
x_{18}	0.1109	0.0034	Documentation

Fig. 5. Values $(w_i + v_i)$ and $(w_i - v_i)$ of the 18 services (the average of $(w_i + v_i)$ is 0.1111 and the average of $(w_i - v_i)$ is 0).

$(w_i - v_i)$ values, were easily affected by other services, the effects were not obvious when the threshold value equaled 0.42. It is apparent that the other services, which have neither a $(w_i + v_i)$ value higher than the average of all $(w_i + v_i)$, nor a negative $(w_i - v_i)$ value, can be provided independently.

5. Discussion

5.1. DEMATEL method to derive interrelated keyfactors

In a totally interdependent system, all of its elements are mutually related, directly or indirectly; thus, any interference with one of the elements affects all the others, making it difficult to find priorities for action. The decision-maker who wants to obtain a specific objective is at a loss if he wants to avoid disturbing the rest of the system while attaining his objective. While the vision of a totally interdependent system leads to passive positions, the vision of a clearer hierarchical structure leads to a linear activism. This neglects feed-back and may engineer many new problems in the process of solving others. DEMATEL was developed in the hope that pioneering and appropriate use of scientific research methods could improve the understanding of a specific *problematique*, a cluster of intertwined problems, and contribute to identification of workable solutions by a hierarchical structure.

To deal with complex problems, structuring the problems by graphical representations and analyzing causal influences aid in illuminating complex issues, systems or concepts. In the social sciences, casual analysis techniques, such as path analysis and structural equation models, have been applied in a number of areas. They help resolve questions about possible causes by providing explanations of effects as a result of previous causes [29–32]. The assumptions and the problems of the models [33–35] make these casual analysis techniques inappropriate to solve the problems which are ambiguous and hard to collect the needed data. Besides, although path diagrams can be used to represent causal flow in a system of variables, they need not imply such a causal flow; in another word, these models can convey linear relationships and test the correlation between variables but the direction of influence of each variable. In the multi-criteria decision making (MCDM) field, the analytic hierarchy process (AHP) and the analytic network process (ANP), both developed by Saaty [36–38], are decision analysis methods that consider both qualitative and quantitative information and combines them by decomposing problems into systematic hierarchies to rank alternatives. Although AHP and ANP provide a mechanism for checking the consistency of the evaluation measures, the structure of the problem should be outlined for choosing an adequate method. In the field of traditional multivariate analysis, the multidimensional scaling (MDS) is a technique for taking the preferences and perceptions of respondents and transforming multivariate data in low-dimensional space. MDS allows one to gain an underlying structure of relations (similarities or dissimilarity), with a goodness of fit test by statistical method, and between samples by providing a geometrical representation of these relations. This result is similar to that of the novel DEMATEL, but the basic concepts of these two algorithms are different (the differences between the DEMATEL and MDS algorithms are explained on Appendix B).

By using the DEMATEL method, we not only know the structure and interrelationships of 18 services, but we can also identify four key services that influence the satisfaction of customers using an SIP Mall. In this paper, we have shown that the DEMATEL method is an appropriative method to delineate the structure of a totally interdependent problem and find the foci for solving the problem. We used the DEMATEL method to divide the needed services into a cause and effect group to better understand the causal relationships. By identifying the structure and interrelationships, we were able to derive the key services that influence the satisfaction of customers using an SIP Mall. These results can be helpful for a decision-maker to allocate resources effectively.

5.2. The focus for an attractive SIP Mall

According to the results, it is essential for an SIP Mall to provide "Verification", "Research Institute Questing", "SIP Grading" and "Technical Standard Specifying" services concurrently, in order to operate an attractive SIP Mall. Based on our research, a reliable "Verification" service is the most important service of a successful SIP Mall. The "Verification" service has the highest $(w_i - v_i)$ value, 0.0078, and affects seven services directly or indirectly. This result reveals that the verification of an SIP is the most important index for SIP users, when they think an SIP Mall could be relied on to collaborate in their chip design project. The "Research Institutions Questing" service is a latent factor for an SIP Mall to attract consumer trade. As shown in Fig. 4, the "Verification (x_1)", "SIP Grading (x_{13})" and "Technical Standard Specifying (x_{15})" services directly affect four services, but the "Research Institutions Questing (x_3)" service affected another six services indirectly via the influence of the "SIP Grading (x_{13})" service. It is necessary for the SIP Mall to search for an institution with the breadth and depth of technical expertise, not only to troubleshoot, but also to add value. Reliable "SIP Grading" and "Technical Standard Specifying" services are also attractive to customers.

Our research revealed eight services whose $(w_i$-$v_i)$ values are negative. This indicates that these services receive more influence from other services than the influences they exert. This means that these services could be improved by resolving the services that connect and affect these negative $(w_i - v_i)$ value services. As shown in Fig. 5, the "Business Process Streamlining (x_5)", "SIP Support and Maintenance (x_6)", "Technology Valuation (x_9)", "Establishing Strategic Partnership (x_{10})", "Licensing Support (x_{11})", "Project Assessment (x_{12})", "Better Price Negotiation (x_{14})", and "Overhead Cost Saving (x_{17})" services, $(w_i - v_i)$ values are negative. Among them, the "Technology Valuation", "Licensing Support", "Better Price Negotiation" and "Overhead Cost Saving" services have a higher than average $(w_i + v_i)$ value with at least one w_i or v_i value higher than the threshold value. These four services are affected by other services. If an SIP Mall wants to provide any of these four services, it should first identify the services which directly affect what they want to provide. The "Business Process Streamlining", "SIP Support and Maintenance", "Establishing Strategic Partnership" and "Project Assessment" services, that do not have a w_i or v_i value higher than the threshold value, can be considered independent services. An SIP Mall can provide these services and ignore the influence of the other services.

The"Financial assistance (x_2)", "Credit Investigation (x_4)", "Increasing Company Awareness (x_7)", "Patent Analysis (x_8)" and "Documentation (x_{18})" services have positive $(w_i - v_i)$ values, but do not have w_i or v_i values higher than the threshold value. These services are neither easily affected by other services, nor play central roles when the threshold value is 0.42. Because the connection with other services is not obvious, an SIP Mall can establish these services independently. Of course, the decision maker(s) could find that these services exert and receive influence by lowering the threshold value of the full direct/indirect matrix. The designers who acquire SIPs for products are much more concerned about the technological benefits of the SIP Mall than the business model and strategic benefits. These services could be provided after an SIP Mall has been operating steadily or at a customer's request.

6. Conclusions

The SIP Mall is a new concept of the SIP business model. The main concern of an SIP Mall is to attract SIP providers and SIP users. An SIP Mall should provide services that enable SIP providers and users to concentrate on centralized technological development. From 18 interrelated services, the literature has shown that four key services that help attract customers to an SIP Mall are: "Verification", "SIP Grading", "Technical Standard Specifying" and "Research Institutes Questing" by using DEMATEL method. These four services influence other services and help determine the satisfaction of customers for an SIP Mall. The SIP Mall founders should allocate resources to satisfy customers about these four services. Customers' confidence and satisfaction with these four services will determine the future of an SIP Mall.

For further research, we suggest determining the relationship between an SIP Mall's performance and the impact of each service, to improve the operation of the SIP Mall. Development strategies, such as business models for SIP trade or incubating start-ups, are vital to an SIP Mall's survival. The public policy for nurturing the SIP Malls, especially for SIP Malls whose main consumers are SMEs, is also a viable research area.

Appendix A. The normalized Initial Direct-Influence Matrix

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}
x_1	0.0000	0.0331	0.0662	0.0297	0.0628	0.0754	0.0423	0.0503	0.0628	0.0560	0.0651	0.0582	0.0697	0.0731	0.0708	0.0617	0.0537	0.0544
x_2	0.0262	0.0000	0.0434	0.0468	0.0445	0.0400	0.0365	0.0411	0.0594	0.0468	0.0457	0.0525	0.0514	0.0640	0.0331	0.0423	0.0503	0.0423
x_3	0.0561	0.0280	0.0000	0.0445	0.0480	0.0434	0.0468	0.0685	0.0742	0.0491	0.0651	0.0525	0.0754	0.0503	0.0640	0.0423	0.0503	0.0641
x_4	0.0336	0.0523	0.0355	0.0000	0.0514	0.0400	0.0457	0.0480	0.0537	0.0525	0.0708	0.0571	0.0525	0.0628	0.0423	0.0343	0.0571	0.0351
x_5	0.0505	0.0430	0.0374	0.0411	0.0000	0.0400	0.0343	0.0411	0.0548	0.0434	0.0548	0.0503	0.0457	0.0468	0.0525	0.0377	0.0548	0.0447
x_6	0.0635	0.0318	0.0336	0.0374	0.0299	0.0000	0.0411	0.0377	0.0411	0.0480	0.0457	0.0537	0.0514	0.0491	0.0480	0.0503	0.0457	0.0411
x_7	0.0262	0.0262	0.0411	0.0336	0.0280	0.0411	0.0000	0.0377	0.0457	0.0491	0.0628	0.0388	0.0457	0.0503	0.0468	0.0582	0.0445	0.0351
x_8	0.0318	0.0336	0.0617	0.0318	0.0355	0.0318	0.0243	0.0000	0.0674	0.0445	0.0514	0.0514	0.0640	0.0594	0.0582	0.0628	0.0537	0.0568
x_9	0.0467	0.0318	0.0654	0.0430	0.0561	0.0355	0.0318	0.0505	0.0000	0.0571	0.0651	0.0594	0.0685	0.0697	0.0594	0.0503	0.0560	0.0484
x_{10}	0.0486	0.0355	0.0318	0.0374	0.0523	0.0505	0.0449	0.0411	0.0449	0.0000	0.0514	0.0491	0.0503	0.0560	0.0628	0.0628	0.0582	0.0496
x_{11}	0.0598	0.0430	0.0561	0.0673	0.0374	0.0598	0.0449	0.0449	0.0523	0.0449	0.0000	0.0434	0.0594	0.0628	0.0514	0.0571	0.0445	0.0496
x_{12}	0.0523	0.0467	0.0430	0.0392	0.0467	0.0430	0.0299	0.0449	0.0411	0.0430	0.0392	0.0000	0.0548	0.0480	0.0491	0.0468	0.0548	0.0460
x_{13}	0.0691	0.0430	0.0691	0.0523	0.0635	0.0561	0.0505	0.0523	0.0617	0.0598	0.0654	0.0561	0.0000	0.0674	0.0617	0.0628	0.0651	0.0520
x_{14}	0.0449	0.0486	0.0355	0.0505	0.0561	0.0505	0.0355	0.0505	0.0598	0.0579	0.0467	0.0542	0.0430	0.0000	0.0468	0.0697	0.0662	0.0460
x_{15}	0.0710	0.0336	0.0617	0.0336	0.0579	0.0542	0.0542	0.0598	0.0579	0.0617	0.0505	0.0523	0.0635	0.0617	0.0000	0.0697	0.0697	0.0738
x_{16}	0.0617	0.0505	0.0523	0.0467	0.0542	0.0654	0.0729	0.0598	0.0486	0.0561	0.0467	0.0449	0.0467	0.0673	0.0673	0.0000	0.0594	0.0460
x_{17}	0.0467	0.0467	0.0430	0.0467	0.0523	0.0392	0.0318	0.0449	0.0486	0.0542	0.0411	0.0505	0.0467	0.0561	0.0542	0.0523	0.0000	0.0399
x_{18}	0.0637	0.0308	0.0596	0.0391	0.0637	0.0473	0.0432	0.0493	0.0617	0.0473	0.0493	0.0493	0.0576	0.0555	0.0596	0.0514	0.0493	0.0000

Appendix B. The differences between the DEMATEL and MDS algorithms

MDS allows one to gain an underlying structure of relations (similarities or dissimilarity), with a goodness of fit test by statistical method, and between samples by providing a geometrical representation of these relations. This result is similar to that of the novel DEMATEL, but the basic concepts of these two algorithms are different:

1. The final product of MDS is to find a representation of items in lower dimensions such that the interterm proximities "nearly match" the original similarities, or distances. The final product of DEMATEL is to obtain an "influence network" and use the "influence" to find the 'key factors' which play central roles in a relationship network (p. 8). DEMATEL also can apply in social network analysis in complex problems for building a network relationship map (NRM).
2. The relationships (similarities, or distances) of items obtained by MDS can be represented as a symmetry matrix, then the correlation (such as max $\rho = \frac{\text{cov}(x,y)}{\sigma_x \sigma_y}$, then find x and y scores) of two elements is the same. For example, the correlation (similarities) or distances (dissimilarity, such as max $Q = -\sum\sum e_{ij}(x_i - x_j)^2$, find $x_1, x_2, \ldots, x_n$ scores) of item x_1 and item x_2 can be represented as a_{12} of the matrix, therefore a_{12} is equal to a_{21}. The result of DEMATEL is usually not a symmetry matrix; this means that the influence from factor x_1 to factor x_2 is not necessary equal to the influence from factor x_2 to factor x_1.
3. The end product of the DEMATEL – the impact-relations map, or network relation map (NRM) – is derived as a result of dynamic process in inter-dependence and feedback among dimensions and criteria (shown as formula 7 on p. 6) of the influence network. The goal of using MDS, which was developed based on maximum likelihood estimation technique in statistics, is not considered a dynamic process, but is used to visualize the proximities of factors in a low-dimensional space. In our paper, MDS is not a suitable method to analyze the 'key factors' in network relation problems.

References

[1] VSI Alliance Architecture Document, Virtual Socket Interface Alliance 1997.
[2] B. Laurent, K. Thierry, A system to validate and certify soft and hard IP, in: Design, Automation and Test in Europe Conference and Exhibition, Munich, Germany, Suppl., 2003, pp. 208–213.
[3] V. Ratford, N. Popper, D. Caldwell, T. Katsioulas, SIP Handbook: Fabless Semiconductor Association, 2003.
[4] G. Moretti, Your core, my design, our problem, EDN 46 (2001) 57–62.
[5] Semiconductor Intellectual Property: The Market Hits Its Stride, Semico Research SC103-05, 2005.

[6] Gartner Press, Gartner, Inc., 24 July 2006.
[7] E. Fontela, A. Gabus, DEMATEL, Innovative Methods, Report No. 2 Structural Analysis of the World Problematique, Battelle Geneva Research Institute, 1974.
[8] I. Al-Jabri, A. Abdul-Gader, Software copyright infringements: an exploratory study of the effects of individual and peer beliefs, Omega 25 (1997) 335–344.
[9] Y. Oshima, Legal protection for semiconductor intellectual property (IP), in: Asia and South Pacific Design Automation Conference, Kitakyushu, Japan, 2003, pp. 551–555.
[10] G.T. Lau, M.A. Razzaque, A. Ong, Gatekeeping in organizational purchasing: an empirical investigation, The Journal of Business and Industrial Marketing 18 (2003) 82–103.
[11] J.T. Macher, D.C. Mowery, T.S. Simcoe, e-Business and disintegration of the semiconductor industry value chain, Industry and Innovation 9 (2002) 155–181.
[12] R.F. Olsen, L.M. Ellram, Buyer–supplier relationships: alternative research approaches, European Journal of Purchasing and Supply Management 3 (1997) 221–231.
[13] T. Osmonbekov, D.C. Bello, D.I. Gilliland, Adoption of electronic commerce tools in business procurement: enhanced buying center structure and processes, The Journal of Business and Industrial Marketing 17 (2002) 151–166.
[14] T.F. Stafford, M.R. Stafford, Industrial buyers' perceptions of industrial salespersons, The Journal of Business and Industrial Marketing 18 (2003) 40–58.
[15] E. Fontela, A. Gabus, The DEMATEL observer: battelle institute, Geneva Research Center (1976).
[16] J.N. Warfield, Societal Systems, Planning, Policy and Complexity, John Wiley & Sons, New York, 1976.
[17] Y.-J. Chiu, H.-C. Chen, J.Z. Shyu, G.-H. Tzeng, Marketing strategy based on customer behaviour for the LCD-TV, International Journal of Management and Decision Making 7 (2006) 143–165.
[18] S. Hori, Y. Shimizu, Designing methods of human interface for supervisory control systems, Control Engineering Practice 7 (1999) 1413–1419.
[19] C.-Y. Huang, J.Z. Shyu, G.-H. Tzeng, Reconfiguring the innovation policy portfolios for Taiwan's SIP Mall industry, Technovation 29 (2007) 744–765.
[20] M. Tamura, H. Nagata, K. Akazawa, Extraction and systems analysis of factors that prevent safety and security by structural models, in: 41st SICE Annual Conference, Osaka, Japan, 2002, pp. 1752–1759.
[21] G.-H. Tzeng, C.-H. Chiang, C.-W. Li, Evaluating intertwined effects in e-learning programs: a novel hybrid MCDM model based on factor analysis and DEMATEL, Expert Systems with Applications 32 (2006) 1028–1044.
[22] N. Bray, Designing for the IP supermarket, in: Fall VIUF Workshop, Orlando, USA, 1999, pp. 8–13.
[23] P. Bricaud, VC rating and quality metrics: why bother?, in: The 3rd International Symposium on Quality Electronic Design, San Jose, USA, 2002, pp. 257–260.
[24] R.G. Dewar, I.D. Carpenter, J.M. Ritchie, J.E.L. Simmons, Assembly planning in a virtual environment, in: Innovation in Technology Management – The Key to Global Leadership, PICMET, Portland, USA, 1997, pp. 664–667.
[25] M. Essig, Purchasing consortia as symbiotic relationships: developing the concept of "consortium sourcing, European Journal of Purchasing and Supply Management 6 (2000) 13–22.
[26] S. Janda, S. Seshadri, The influence of purchasing strategies on performance, The Journal of Business and Industrial Marketing 16 (2001) 294–306.
[27] R. Saxby, P. Harrod, Test in the emerging intellectual property business, Design and Test of Computers, IEEE 16 (1999) 16–18.
[28] ITIS, 2003 Semiconductor Industry Yearbook (in Chinese), Taiwan, Industrial Technology Intelligence Services, 2004.
[29] M.A. Badri, D. Davis, D. Davis, Operations strategy, environmental uncertainty and performance: a path analytic model of industries in developing countries, Omega 28 (2000) 155–173.
[30] T.A. Byrd, T.E. Marshall, Relating information technology investment to organizational performance: a causal model analysis, Omega 25 (1997) 43–56.
[31] S.L. Hershberger, The growth of structural equation modeling: 1994–2001, Structural Equation Modeling 10 (2003) 35–46.
[32] B.S. Ragu-Nathan, C.H. Apigian, T.S. Ragu-Nathan, Q. Tu, A path analytic study of the effect of top management support for information systems performance, Omega 32 (2004) 459–471.
[33] X. Fan, B. Thompson, L. Wang, Effects of sample size, estimation methods, and model specification on structural equation modeling fit indexes, Structural Equation Modeling 6 (1999) 56–83.
[34] P.E. Meehl, N.G. Waller, The path analysis controversy: a new statistical approach to strong appraisal of verisimilitude, Psychological Methods 7 (2002) 283–300.
[35] R.R. Wilcox, How many discoveries have been lost by ignoring modern statistical methods?, The American psychologist 53 (1998) 300–314
[36] T.L. Saaty, A scaling method for priorities in hierarchical structures, Journal of Mathematical Psychology 15 (1977) 234–281.
[37] T.L. Saaty, The Analytical Hierarchy Process: Planning Priority, Setting Resource Allocation, McGraw-Hill, New York, 1980.
[38] T.L. Saaty, Decision Making with Dependence and Feedback: The Analytic Network Process, RWS Publications, Pittsburgh, 1996.