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ScienceDirect
Expert Systems with Applications 33 (2007) 1042–1053
Expert Systems with Applications
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A multi-criterion interaction-oriented model with proportional rule for designing supply chain networks

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Abstract

Supply chain management has offered a way to improve the industrial environment becomes more competitive. While, the commonly seen methodologies may be effective in solving the production–distribution problem only from supplier- or customer-oriented consideration, those cannot present the interactive relationship between upstream and downstream enterprises. In the competitive semiconductor industry environment, considering the viewpoints of the supplier and consumer simultaneously is particularly required, because multiple manufacturing and demanding steps are performed at separate situations, concurrently. In this paper, we propose an interaction-oriented approach, which bases on the analytic hierarchy process (AHP) methodology and proportional rule, to solve the semiconductor distribution problem with multiple quantitative and qualitative criteria. The developed approach gives an expected satisfaction for the all participators of the whole chain while the cooperative information is shared perfectly and effectively. Analysis results demonstrate the proposed methodology is efficient and effective through a real world case study.

Keywords: Supply chain management; Interaction-oriented approach; Analytic hierarchy process; Multiple criteria; Proportional rule

1. Introduction

Christopher (1992) states that a suitable definition of supply chain is "a network of organizations that are involved, through upstream and downstream linkages, in different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer" from a logistical point of view. Supply chain management, offers a way to improve the industrial environment becomes more competitive, and involves planning and managing the flow of information, material, and product through multi-echelon of design, production/manufacturing, transportation and distribution until it reaches the customer (Christopher, 1992; Sha & Che, 2005, 2006).

In semiconductor industry, modeling the supply chain is particularly critical. Semiconductor fabrication, assembly and test facilities represent quite large capital investments. The essence of supply chain management has been considered as the integration of business activities to serve end customers by establishing a strategic alliance of partners. The relationships in a supply chain may take on a variety of legal forms (Ellram, 1991). Fig. 1 presents the relationship between the dependent natures of supplier-customer relations. For the semiconductor supply chain, the interrelation between supplier and customer tends to make a decision problem with multiple selections; that is in the quadrant: strategically cooperative. Thus, the competitive of this industry is corresponded supplier and customer efficient cooperation. Supply chain management can help in achieving the goals of supplier and customer satisfaction for the semiconductor industry simultaneously.

For a winning combination (Bowerson, 1990; Sha & Che, 2005), retailers, manufacturers and logistics service

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doi:10.1016/j.eswa.2006.08.015

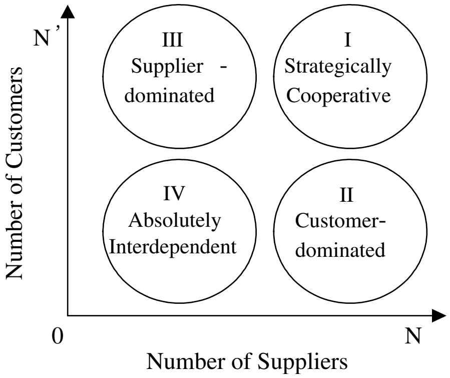

Fig. 1. Relationships between supplier and customer (Sha & Che, 2004, 2005).

companies teams together. Schonberger (1990) and Moody (1994) advocate long term, selective partnerships for providing benefits to all sides of the relationship. Papazoglou, Ribbers, and Tsalgatidou (2000), Mikhailov (2002) and Sha and Che (2006) claimed that the key issue in forming a virtual enterprise is to select agile, competent, and compatible partners, and Korhoren, Huttunen, and Eloranta (1998) and Davis and O'Sullivan (1999) stated that the partner selection process is an important function for the information management systems of extended virtual enterprises. The selective partnerships include deciding on appropriate upstream suppliers/vendors and downstream manufacturers/distributors for specific enterprise.

By the fact, vendor/distributor selection decisions are complicated that potential options may be evaluated on more than one criterion. Dickson (1966) identified 23 criteria that have been considered by purchasing managers in various vendor selection problems. More recently, multi-criteria evaluation and potent methods, were illustrate by Weber, Current, and Benton (1991, 1993, 1996) and Wang and Che (2006), are particularly important for selecting vendors/suppliers for achieving the competitive advantage. Muralidharan, Anatharaman, and Deshmukh (2002) proposed a multiple criteria model to aid decision makers with varying degrees of importance to reach consensus in rating alternative suppliers. In like wise, the distributor selection is an important impact in supply chain environment. In semiconductor industry, the capital investments are particularly large. Consequently, partner selection is the most important activity to establish strategic alliance for competitive advantage enhancement of this supply chain.

According to aforesaid literatures, efficient integration could obtain tangible and intangible benefits simultaneously. This paper proposes an interaction-oriented based approach, which bases on AHP methodology and proportional rule, to solve the semiconductor supply chain distribution problem give an expected optimal satisfaction by proportional rule. The AHP (Saaty, 1980, 1983), is a scoring method that was designed to visually structure a complex decision problems involving multiple criteria, is based on the three principles: decomposition, comparative judgments, and the synthesis of priorities. The AHP is a theory of measurement for dealing with quantifiable and intangible criteria that has been applied to numerous areas, such as decision theory and conflict resolution (Vargas, 1990). The operating process of the AHP can be summarized as follows (Saaty, 1980, 1983):

Step 1: Create a decision hierarchy by breaking down the problem into a hierarchy of decision elements.
Step 2: Collect input by a pair-wise comparison of decision elements.
Step 3: Determine whether the input data satisfies a "Consistency Test". If it does not, go back to Step 2 redo the pair-wise comparisons.
Step 4: Calculate the relative weights of the decision elements.
Step 5: Aggregate the relative weights to obtain scores and hence rankings for the decision alternatives.

Semiconductor supply chain modeling is a team effort. The AHP is one available method for forming a systematic framework for group interaction and group decision making (Saaty, 1982). Dyer and Forman (1992) show the advantages of AHP in a group setting as follows: both tangibles and intangibles, individual values and shared values can be included in an AHP-based group decision process, the discussion in a group can be focused on objectives rather than on alternatives, the discussion can be structured so that every factor relevant to the decision is considered in turn, and in a structured analysis, the discussion continues until all relevant information from each individual member in the group has been considered and a consensus choice of the decision alternative is achieved.

This proposed approach is preceded by an analysis in order to define the best potential distribution points and release quantity for the upstream companies, to determine the feasible distribution downstream cooperators and volume and to gather extensive information on them. Thus the objective for the proposed approach is to assist in deciding which companies of the feasible cooperators will be included in the distribution network of a semiconductor supply chain and how much release quantity will obtain from its upstream suppliers. The application of this approach is illustrated through a case study on sustainable supply chain design of the complex semiconductor industry. In order to obtain an quality solution, this paper emphasized to present an efficient and systematic approach for modeling the distribution behavior of semiconductor supply chain that satisfies the demand of end customers.

The paper is organized as follows. Section 2 reviews the relevant literature on partner selection with multiple criteria and AHP approach. Section 3 discusses the research objectives clearly. Base on AHP model and proportional rule, the interaction-oriented methodology is capable of identifying a supply chain distribution decision as discussed in section 4. Section 5 illustrates the effectiveness and efficiency of the proposed research approach in the actual semiconductor industry environment. In section 6, sensitivity analyses would be performed by changing linkage weights for exploring the response of solutions with possible synergetic partnership of distribution network. Section 7 summarizes the conclusions and remarks of this research.

2. Problem statement and research objectives

In the environment of semiconductor industry, in order to make decision for solving the relationship and component and/or product distribution between relative cooperators, developing a systematic and efficient mathematical method is necessary; in which all procedure of the industry from raw material supply to product distribution of semiconductor supply chain. Hence, in this paper, the attention is focused on a semiconductor supply chain distribution network with all cooperators in a complex link as Fig. 2. Distribution links are as parts of the supply chain network, and their functions are taken into consideration though supplier supply and customer demand. The basic premises concerning semiconductor supply chain distribution for the proposed approach are the following: (1) supplier supply and customer demand are confined to a single product, and (2) the decision hierarchy architecture of each company could be different, but decision elements in each hierarchy architecture of the specific company for evaluating its cooperators that belong the same echelon must be the same.

The objective of this paper is to model and simulate behavior of the supply chain in a semiconductor environment. The hierarchy architectures of each organization and the pair-wise comparison weights are described by individual organization, such as Taiwan Semiconductor Manufacturing Company (TSMC), of Taiwan, ROC, constructs the hierarchy structures of its upstream suppliers and downstream manufacturers/distributors and identifies the relative weights of decision elements (factors) by pairwise comparison; and other organizations do the same task for itself. Then, integration of all companies is formally represented and performs decision making according to the integration-oriented approach is proposed in this paper.

3. System framework

In this paper, we consider the multiple criteria and a number of participators and we evaluate the linkage weight between the two participators of the entire chain. Therefore, it is a large scale to evaluate all the participators and find the suitable participators. Simultaneously, the appropriate production quantities of each selected participators and shipping quantities between two participators are also found. For conducting this complex distribution network design problem, an interaction-oriented model, which consists of seven steps, is suggested. The specific pro-

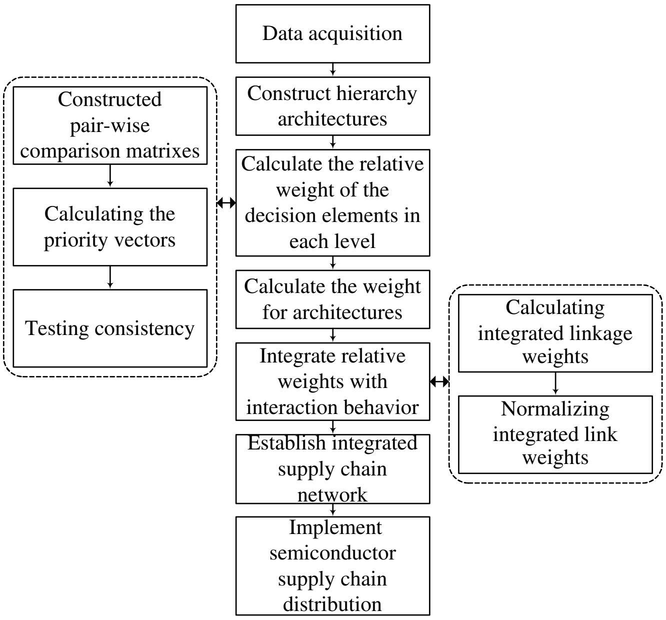

Fig. 3. Interaction-oriented model procedure.

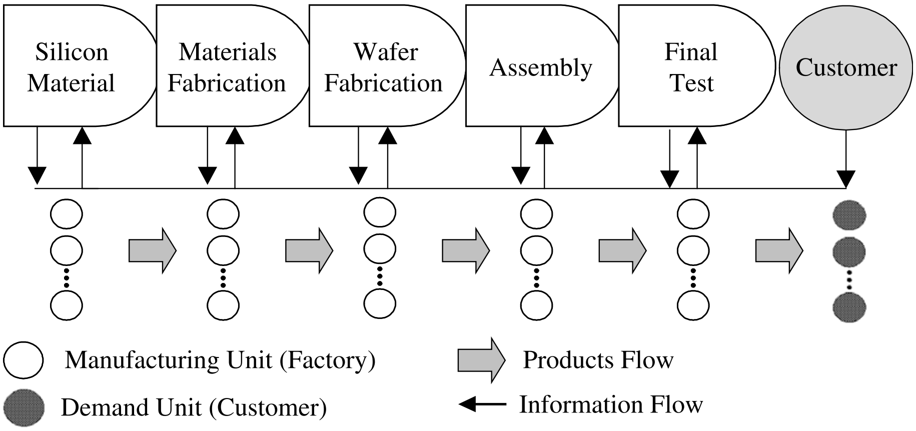

Fig. 2. Semiconductor supply chain distribution network.

cedure of each phase was shown as Fig. 3. It was formulated based on following steps for performing decision-making.

4. Participators selection model

To analyze the semiconductor supply chain distribution behavior, an interaction-oriented model that is based on the AHP model and proportional rule and designed to produce a suitable distribution with explicit satisfaction of all participators was proposed in previous section. In this section, the specific processes of each step would be explained. We also develop the decision support system on the basis of the selection model. This system helps decision maker to select the suitable participators and appropriate quantities of producing and shipping, which can construct a partner relationship among participators for performing semiconductor production.

Step 1: Data acquisition

The proposed procedure begins with the data acquisition step, which collects the required evaluation data including: decision elements for identifying performance and comparison scale for element. These data must be accurately collected in order to assure the reliability of the model operation.

Step 2: Construct hierarchy architectures

For constructing the relationship with each other cooperator in the semiconductor supply chain, using the decomposed technique to establish the hierarchy architectures separately for upstream material suppliers and downstream product manufacturers/distributors of each company. In this step, for all hierarchy architectures, number of levels and decision elements (factors) are determined definitely, it appropriate is 7 ± 2; decision marker would be confused to handle more than seven or nine decision elements (i.e., criteria, alternatives) simultaneously (Miller, 1956).

Scilicet, the pair-wise comparisons will be incorrectness and non-consistency, if the number of decision element is overmuch in each level. By reason of people cannot obtain the correct ratio scales and must spend much time for pair-wise comparisons on the over-complex situation.

Step 3: Calculate the relative weight of the decision elements in each level

This step is completed through making a go of following three sub-steps availably (Sha & Che, 2004, 2005).

(a) Constructed pair-wise comparison matrixes

The purpose of this sub-step is to obtain the relative decision elements of importance or contribution for each level, namely, every decision elements are performed the pair-wise comparisons for each other of the same level and classified category. Then, use 1 to 9 scales to demonstrate the relative degree of importance, e.g., 1, which indicates two factors (criteria) are equally important to the objective; 9, which indicates one factor is absolutely more important than another factor. For different statements, the scales may be adjusted competently, namely, can use 1 to 5 scales or other choices, and could use rationales as compromise is needed.

A_n the nth $(n = 1, 2, \ldots, N)$ decision element (criterion or sub-criterion) for the upstream suppliers or downstream manufacturers/distributors by a particular organization. The relative scale, the quantified comparisons on pairs A_i and A_j $(i,j = 1, 2, \ldots, n)$, of pair-wise comparison is denoted by a_{ij}. Then, the pair-wise comparison $n \times n$ matrix is expressed as

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{bmatrix} \tag{1}$$

where $i,j = 1, 2, \ldots, n$, and $a_{ij} = 1/a_{ji}$.

Since $i = j$, the value a_{ij}, of the diagonal within pair-wise comparison matrix, must consist of 1's; to put it another way, the decision element compares with itself. As the real weight w_n of the nth decision element is known, the scale a_{ij} would be equaled w_i/w_j. Thereby, the pair-wise comparison matrix would be written as

$$A = [a_{ij}] = \left[\frac{w_i}{w_j}\right] = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & \cdots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \vdots \\ w_n/w_1 & \cdots & \cdots & w_n/w_n \end{bmatrix} \tag{2}$$

where

$$w = [w_1 w_2 \ldots w_n]^{\mathrm{T}}.$$

There are four ways that can be used for setting the priorities: (1) consensus, (2) vote or compromise, (3) geometric mean of the individuals' judgments, and (4) separate models or players (Dyer & Forman, 1992).

(b) Calculating the priority vectors

For expressing the relative degree of importance between decision elements, the priority vector (eigenvector), which is solved by eigenvalue-method, is more useful. The principal eigenvector could be computed, which becomes the vector of priorities when normalized. The formula to get the eigenvector is

$$Aw = \lambda_{\max} w \tag{3}$$

where

$\lambda_{\max}$ is the largest eigenvalue of A,

w is the eigenvector.

(c) Testing consistency

Since there are more decision elements for each pair-wise comparison, the consistency index (CI), that measures the whole consistency of judgment for each comparison matrix and the hierarchy architecture, is more important for the complex decision problem. Consistency ratio (CR) is useful for this task, and the accepted upper limit values for CR is 0.1 for well judgment. CR would be calculated by

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{4}$$

where

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1} \tag{5}$$

Random index (RI) is obtained by n from random index table as Table 1 below. If the consistency test is not eligible ($\mathrm{CR} > 0.1$), go to step 1.

Step 4: *Calculate the weight for architectures*

This step calculates the synthetic prior weights (SP), the magnitude of relative importance of corporation j, to upstream suppliers and/or downstream distributors/manufacturers for each organization. The Prior weight is given by

$$\mathrm{SP} = [\mathrm{SP}_j] = [P_i^T \times P_{ij}] \tag{6}$$

where

P_i is the weight vector of criteria i,

P_{ij} is the weight vector of the cooperators j with respect to criteria i,

$i = 1, 2, \ldots, n,$

$j = 1, 2, \ldots, m.$

Step 5: *Integrate relative weights with interaction behavior*

The purpose of this step is to develop an approach to reveal the relationship between connected cooperators. In order to provide an authentic reliance about constructing, interpreting, and solving semiconductor supply shin distribution problem, the interrelation between point of view of suppliers and consumers would be considered simultaneously. Following three sub-steps can describe this phase definitely.

(a) Calculating integrated linkage weights

Through above steps, the prior weights, of viewpoint of the organization to its specific cooperator, could be obtained powerfully. Correspondingly, this cooperator also holds the others to that organization from its viewpoint. Thereby, the integrated linkage weight, between the xth node of echelon e and the yth node of echelon $e+1$, denoted by $\mathrm{IW}^{e(x),e+1(y)}$ ($x = 1, 2, \ldots, l, y = 1, 2, \ldots, m, e = 1, 2, \ldots, n$), have integrated viewpoints from both of them, would be formulated by multiplication methodology, as

$$\mathrm{IW}^{e(x),e+1(y)} = \mathrm{SP}^{e(x),e+1(y)} \times \mathrm{SP}^{e+1(y),e(x)} \tag{7}$$

where

$\mathrm{SP}^{e(x),e+1(y)}$ is the prior weight from node x in echelon e to node y in echelon $e+1$,

$\mathrm{SP}^{e+1(y),e(x)}$ is the prior weight from node y in echelon $e+1$ to node x in echelon e.

(b) Normalizing integrated link weights

The completion of the above sub-step figured out integrated linkage weights indubitably. For expressing the relative relationship specifically, this sub-step emphasizes to normalize integrated linkage weights, for each cooperator of a particular organization. Herewith, the normalization weights ($\underline{\mathrm{IW}}$) would be formally defined as

$$\underline{\mathrm{IW}}^{e(x),e+1(y)} = \frac{\mathrm{IW}^{e(x),e+1(y)}}{\sum_{y=1}^{m} \mathrm{IW}^{e(x),e+1(y)}} \tag{8}$$

Step 6: *Establish integrated supply chain network*

In order to provide a foundation for further system implementation, the integrated supply chain network should be established briefly. According to the result of previous steps, the integrated supply chain network could be represented in matrix form as

$$\underline{\mathrm{IW}} = [\underline{\mathrm{IW}}^{e(x),e+1(y)}] \tag{9}$$

Step 7: *Implement semiconductor supply chain distribution*

This step will provide a feasible distribution decision by analyzing and evaluating for a given statement of semiconductor industry. It is the decision procedure that provides the distribution information for decision makers.

There are two network situations, of integrated semiconductor supply chain for analyzing and evaluating the distribution decision, would be disposed disjunctively as follows.

Situation 1:

Making the decision of the quantity of distribution for each node is by normalize integrated linkage weights (IW). There are five assumptions for conducting effectively as

1. The quantity is provided by the first echelon, which is equal, the need of the latest echelon.

Table 1
Random index table (Golden et al., 1989)

n	3	4	5	6	7	8	9
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.45

2. Without other constrains for each node and each linkage.
3. The subsistent relations must be keeps.
4. The production capacity of each cooperator (node) is always large enough to adapt demand.
5. Each node only exists in one echelon.

Based on this situation, the distribution model, proportional rule, is proposed and expressed in the following equation:

$$Q^{e(x),e+1(y)} = \sum_{x=1}^{l} \left(Q^{e-1(x),e(y)} \times \underline{\mathrm{IW}}^{e(x),e+1(y)}\right) \tag{10}$$

where $Q^{e(x),e+1(y)}$ is the distribution quantity from node x of echelon e to node y of echelon $e+1$ and $\underline{\mathrm{IW}}^{e(x),e+1(y)}$ is the normalize integrated linkage weight between node x of echelon e and node y of echelon $e+1$.

Situation 2:

The subsistent relations are not always keeps, if the correlation is not acceptable (e.g., $\underline{\mathrm{IW}}^{e(x),e+1(y)} < 0.2$) between two nodes. The quantity of distribution for each node will be set by integrated linkage weights ($\underline{\underline{\mathrm{IW}}}$). Four assumptions for conducting effectively are as #1, #2, #4, and #5 in situation 1.

Based on this situation, the distribution model, proportional rule, is proposed and expressed in the following equation:

$$Q^{e(x),e+1(y)} = \sum_{x=1}^{l} \left(Q^{e-1(x),e(y)} \times \underline{\underline{\mathrm{IW}}}^{e(x),e+1(y)}\right) \tag{11}$$

where

$$\underline{\underline{\mathrm{IW}}}^{e(x),e+1(y)} = \frac{\underline{\mathrm{IW}}^{e(x),e+1(y)}}{\sum_{x=1}^{l} \underline{\mathrm{IW}}^{e(x),e+1(y)}} \tag{12}$$

and $\underline{\mathrm{IW}}^{e(x),e+1(y)}$, is the integrated linkage weight between node x of echelon e and node y of echelon $e+1$, is calculated as follows:

$$\underline{\mathrm{IW}}^{e(x),e+1(y)} = \begin{cases} \underline{\mathrm{IW}}^{e(x),e+1(y)} & \text{if } \underline{\mathrm{IW}}^{e(x),e+1(y)} \geqslant c \\ 0 & \text{otherwise} \end{cases} \tag{13}$$

and

$$\underline{\mathrm{IW}}^{e(y1),e+1(y2)} \text{ equals 0 if } \sum_{x=1}^{l} \underline{\mathrm{IW}}^{e(x),e+1(y_1)} \text{ is 0} \tag{14}$$

where

c is a acceptable value of integrated linkage weight.

The above steps 2–4 are ordered processes are similar with AHP for dealing with complex decision problems. In step 2, decision hierarchy structures must be constructed for upstream and downstream cooperators of each organization. Steps (#5 to #7) focus on the integration of relative cooperators, establish supply chain network, and then implement distribution.

5. Model application

The objective of this application study was to illustrate the effectiveness and efficiency of the proposed research approach in the actual semiconductor industry environment. Specifically, the application involved several selectable partnerships for each enterprise for the strategic alliance at the supply chain of semiconductor industry in Taiwan, ROC, using the application of the decision support software EXPERT-CHOICE. This cooperation started a supply chain partnership to improve industry competitive via more efficient integrated enterprises.

Following the procedure depicted above, this real-world application was applied to the {1-3-3-4-1} network topology. Herein, the $\{E_0 - E_1 - E_2 - E_3 - E_4\}$ denotes for the number of enterprises in the zeroth echelon (silicon material supply), the number of enterprises in the first echelon (materials fabrication), the number of enterprises in the second echelon (wafer fabrication), the number of enterprises in the third echelon (assembly), the number of

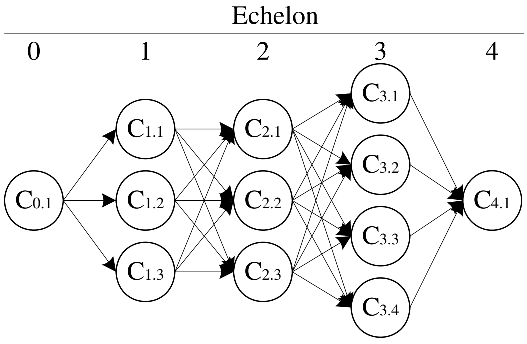

Fig. 4. {1-3-3-4-1} supply chain network topology.

Table 2
Evaluation criteria of WE

For upstream supplier

Criterion	Description
A. Price	Unit product price
B. Matching	Tune of conjugation with products
C. Delivery	Capability of delivery on time
D. Quality	Quality of incoming material

For downstream production/distributor

Criterion	Sub-criterion	Description
E. Quality	E1. REJ (IQC)	Incoming quality control
	E2. Outlier control	Capability of processing project for per annum
	E3. SPC	Statistic process control of O/S
	E4. CAR	Correction abnormal record
F. Yield		The yield of O/S or assembly
G. Delivery		Capability of delivery on time
H. Price		Unit product price
I. Service		Production capacity for fitting demand

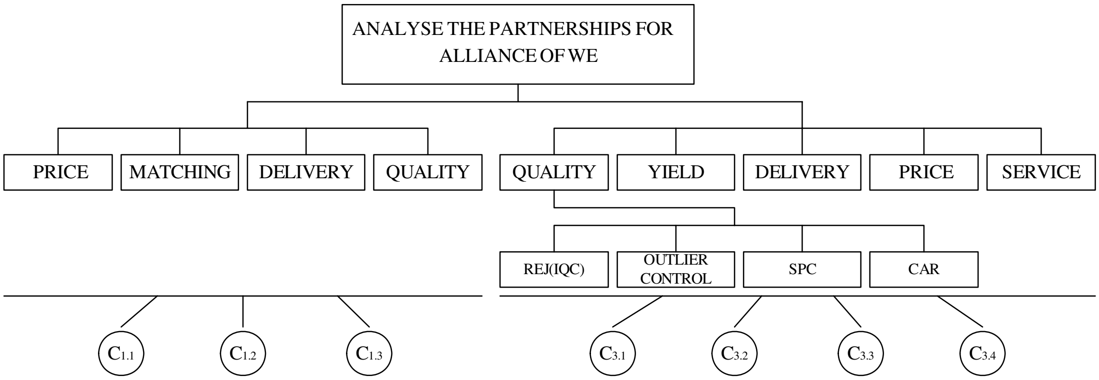

Fig. 5. The AHP-hierarchy for analyzing the partnerships of WE.

enterprises in the fourth echelon (Test). The network topology would be modified by real status. The particular architecture, of semiconductor supply chain, is illustrated after as shown in Fig. 4, would be constructed by collecting the real relation between enterprises. $C_{i,j}$ represents cooperator i in echelon j.

The node $C_{2.1}$ expresses W Electronics (WE) in the Hsinchu Science-based Industrial Park, Taiwan, ROC.

Table 3
The pair-wise comparison matrixes

For upstream supplier

Criterion	A	B	C	D
A		0.4	0.4	3.0
B			1.0	8.0
C				8.0
D				

For downstream distributor/manufacture

Criterion	E	F	G	H	I
E		1.3	1.3	0.7	2.6
F			1.0	0.6	2.0
G				0.6	2.0
H					3.5
I					

Sub-criterio	E1	E2	E3	E4
E1		0.4	0.4	3.0
E2			1.0	8.0
E3				8.0
E4				

	Criterion A			Criterion B			Criterion C			Criterion D		
	Cooperator			Cooperator			Cooperator			Cooperator		
Cooperator	$C_{1.1}$	$C_{1.2}$	$C_{1.3}$	$C_{1.1}$	$C_{1.2}$	$C_{1.3}$	$C_{1.1}$	$C_{1.2}$	$C_{1.3}$	$C_{1.1}$	$C_{1.2}$	$C_{1.3}$
$C_{1.1}$		2.8	5.3		2.8	5.3		0.3	0.2		3.0	0.5
$C_{1.2}$			1.9			1.9			0.5			0.2
$C_{1.3}$												

	Criterion F				Criterion G				Criterion H				Criterion I			
	Cooperator				Cooperator				Cooperator				Cooperator			
Cooperator	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$
$C_{3.1}$		2.0	3.1	0.8		2.0	6.4	0.7		0.8	0.9	0.6		0.8	2.9	1.9
$C_{3.2}$			1.6	0.4			3.2	0.3			1.1	0.8			3.6	2.4
$C_{3.3}$				0.3				0.1				0.7				0.7
$C_{3.4}$																

	Sub-criterion E1				Sub-criterion E2				Sub-criterion E3				Sub-criterion E4			
	Cooperator				Cooperator				Cooperator				Cooperator			
Cooperator	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$
$C_{3.1}$		0.6	1.1	0.3		4.1	1.6	1.6		0.4	2.0	1.1		0.5	0.2	0.4
$C_{3.2}$			1.7	0.5			0.4	0.4			5.1	2.7			0.5	0.7
$C_{3.3}$				0.3				1.0				0.5				1.5
$C_{3.4}$																

Table 4
Relative weights and priority scores of WE for the alliance decision

For upstream supplier				For downstream production/distributor			
Criterion	Relative weight	Node	Priority scores	Criterion/sub-criterion	Relative weights	Node	Priority scores
A	0.156	$C_{1.1}$	0.648	E	0.232		
		$C_{1.2}$	0.230	E1	0.289	$C_{3.1}$	0.152
		$C_{1.3}$	0.122			$C_{3.2}$	0.241
B	0.397	$C_{1.1}$	0.648			$C_{3.3}$	0.138
		$C_{1.2}$	0.122			$C_{3.4}$	0.469
		$C_{1.3}$	0.230	E2	0.141	$C_{3.1}$	0.410
C	0.397	$C_{1.1}$	0.093			$C_{3.2}$	0.100
		$C_{1.2}$	0.292			$C_{3.3}$	0.250
		$C_{1.3}$	0.615			$C_{3.4}$	0.250
D	0.050	$C_{1.1}$	0.300	E3	0.285	$C_{3.1}$	0.201
		$C_{1.2}$	0.100			$C_{3.2}$	0.512
		$C_{1.3}$	0.600			$C_{3.3}$	0.100
						$C_{3.4}$	0.187
				E4	0.285	$C_{3.1}$	0.100
						$C_{3.2}$	0.200
						$C_{3.3}$	0.420
						$C_{3.4}$	0.280
				F	0.181	$C_{3.1}$	0.298
						$C_{3.2}$	0.151
						$C_{3.3}$	0.097
						$C_{3.4}$	0.354
				G	0.181	$C_{3.1}$	0.318
						$C_{3.2}$	0.161
						$C_{3.3}$	0.050
						$C_{3.4}$	0.471
				H	0.316	$C_{3.1}$	0.196
						$C_{3.2}$	0.251
						$C_{3.3}$	0.222
						$C_{3.4}$	0.331
				I	0.090	$C_{3.1}$	0.317
						$C_{3.2}$	0.405
						$C_{3.3}$	0.111
						$C_{3.4}$	0.167

Then, the related decision criteria could be obtained authentically in Step 1. These criteria are used for the ranking of proposed partnerships of WE's upstream supplier and downstream production/distributor, these factors that may potentially affect the cooperation decision. These factors, were used to evaluate the partnerships veritably and singled out a list as Table 2, were initially presented by the team of outsourcing of WE. In Table 2, the most important criteria identified were divided into four categories: A, B, C, and D for the upstream and five categories: E, F, G, H and I for the downstream. For the sake of conciseness of the paper, the technique, its the details would not be described again, for data acquisition of other nodes (enterprises) is the same with WE.

In Step 2, all decision elements are gathered to the full. In order to evaluate the importance of these critical success factors and to analyze the performance of partnerships of WE, the success factors and cooperators for alliance are structured into a form of a hierarchy as shown in Fig. 5.

The overall importance, of the form "How many times is the row criterion more important than the column criterion?" of the critical criteria obtained by the team of outsourcing of WE is presented in following matrixes. The pair-wise comparison matrixes, for upstream and downstream enterprises respectively, derive relative weights of alliance criteria, were as following Table 3.

Herein, these relative weights, were summarized in Table 4, represent the WE outsourcing team's judgments on the relative importance of the alliance criteria to the alliance decision. Sets of synthesized priority scores, were also recapitulated in Table 2, and were produced by the relative weights for the three upstream and four downstream cooperators of WE.

In Step 3, after constructing the complete hierarchy architectures, pair-wise comparisons, of decision criteria, attributes and cooperators, has put to use rather than using absolute measurement scales since absolute measurement tends to be very subjective. The overall synthetic prior weight for each upstream and downstream cooperator is outlined in Table 3.

In Steps 4 and 5, according to oriented viewpoints of supplier and customer for each organization, the prior weights are ready for linking enterprises. To combine these two viewpoints, the integrate viewpoint is formulated

Table 5
Linkage weights of viewpoints of supplier and customer

For upstream supplier		For downstream customer		Integrate linkage weights (IW)
Relationship	Prior weight	Relationship	Prior weight	
$C_{0.1} \leftarrow C_{1.1}$	1.000	$C_{0.1} \rightarrow C_{1.1}$	0.310	0.310
$C_{0.1} \leftarrow C_{1.2}$	1.000	$C_{0.1} \rightarrow C_{1.2}$	0.110	0.110
$C_{0.1} \leftarrow C_{1.3}$	1.000	$C_{0.1} \rightarrow C_{1.3}$	0.580	0.580
$C_{1.1} \leftarrow C_{2.1}$	0.410	$C_{1.1} \rightarrow C_{2.1}$	0.250	0.103
$C_{1.2} \leftarrow C_{2.1}$	0.205	$C_{1.2} \rightarrow C_{2.1}$	0.152	0.031
$C_{1.3} \leftarrow C_{2.1}$	0.384	$C_{1.3} \rightarrow C_{2.1}$	0.536	0.206
$C_{1.1} \leftarrow C_{2.2}$	0.235	$C_{1.1} \rightarrow C_{2.2}$	0.320	0.075
$C_{1.2} \leftarrow C_{2.2}$	0.422	$C_{1.2} \rightarrow C_{2.2}$	0.422	0.178
$C_{1.3} \leftarrow C_{2.2}$	0.343	$C_{1.3} \rightarrow C_{2.2}$	0.302	0.104
$C_{1.1} \leftarrow C_{2.3}$	0.127	$C_{1.1} \rightarrow C_{2.3}$	0.430	0.055
$C_{1.2} \leftarrow C_{2.3}$	0.221	$C_{1.2} \rightarrow C_{2.3}$	0.426	0.094
$C_{1.3} \leftarrow C_{2.3}$	0.652	$C_{1.3} \rightarrow C_{2.3}$	0.162	0.106
$C_{2.1} \leftarrow C_{3.1}$	0.751	$C_{2.1} \rightarrow C_{3.1}$	0.245	0.184
$C_{2.2} \leftarrow C_{3.1}$	0.111	$C_{2.2} \rightarrow C_{3.1}$	0.122	0.014
$C_{2.3} \leftarrow C_{3.1}$	0.138	$C_{2.3} \rightarrow C_{3.1}$	0.151	0.021
$C_{2.1} \leftarrow C_{3.2}$	0.315	$C_{2.1} \rightarrow C_{3.2}$	0.239	0.075
$C_{2.2} \leftarrow C_{3.2}$	0.132	$C_{2.2} \rightarrow C_{3.2}$	0.214	0.028
$C_{2.3} \leftarrow C_{3.2}$	0.553	$C_{2.3} \rightarrow C_{3.2}$	0.552	0.305
$C_{2.1} \leftarrow C_{3.3}$	0.250	$C_{2.1} \rightarrow C_{3.3}$	0.197	0.049
$C_{2.2} \leftarrow C_{3.3}$	0.643	$C_{2.2} \rightarrow C_{3.3}$	0.420	0.270
$C_{2.3} \leftarrow C_{3.3}$	0.107	$C_{2.3} \rightarrow C_{3.3}$	0.177	0.019
$C_{2.1} \leftarrow C_{3.4}$	0.121	$C_{2.1} \rightarrow C_{3.4}$	0.319	0.039
$C_{2.2} \leftarrow C_{3.4}$	0.276	$C_{2.2} \rightarrow C_{3.4}$	0.244	0.067
$C_{2.3} \leftarrow C_{3.4}$	0.603	$C_{2.3} \rightarrow C_{3.4}$	0.120	0.072

by multiplication methodology $\mathrm{SP}^{e(x),e+1(y)} \times \mathrm{SP}^{e+1(y),e(x)}$. Then, the integrated linkage weights (IW) are calculated and also shown in Table 5.

In Step 6, the integrated semiconductor supply chain network would be established with $\underline{\mathrm{IW}}$ or $\underline{\underline{\mathrm{IW}}}$, which had been represented in above table.

Up to this point, the integrated network is ready for a supply chain distribution decision. In Step 7, since the total quantity of batch size of customer demand is 1000 units, Fig. 6, are demonstrated briefly by $\underline{\mathrm{IW}}$ and $\underline{\underline{\mathrm{IW}}}$ that are depicted by separately placing their values with 100% out of and in brackets attached to arcs, illustrate two network situations herein. The results of the two illustrative network situations are given in Table 6(a) and (b). In Table 6(a), the results of situation 1 were obtained, where the customer demand is satisfied and the total supplier and customer preferences are optimized. In Table 6(b), the results of the same supply chain distribution problem, since the acceptable value of integrated linkage weight c is more than 0.2.

The results of situations 1 and 2 show that nodes $C_{1.1}$ and $C_{1.3}$ of echelon 1 and nodes $C_{3.1}$, $C_{3.2}$, and $C_{3.3}$ of echelon 3 are existed in both situations, and other nodes at echelon 2 are indwelled in both situations. In situation 2, the lower limit of acceptable value of integrated linkage weight c is given and equals 0.2, that linkage weights $\underline{\mathrm{IW}}^{0(1),1(2)}$, $\underline{\mathrm{IW}}^{1(2),2(1)}$, $\underline{\mathrm{IW}}^{2(1),3(3)}$, $\underline{\mathrm{IW}}^{2(1),3(4)}$, $\underline{\mathrm{IW}}^{2(2),3(1)}$, $\underline{\mathrm{IW}}^{2(2),3(2)}$, $\underline{\mathrm{IW}}^{2(2),3(4)}$, $\underline{\mathrm{IW}}^{2(3),3(1)}$, $\underline{\mathrm{IW}}^{2(3),3(3)}$, and $\underline{\mathrm{IW}}^{2(3),3(4)}$ are incompetent and will be taken away from this supply chain distribution network. And, while $\Sigma_{x=1}\underline{\mathrm{IW}}^{0(x),1(2)}$ and $\Sigma_{x=1\sim3}\underline{\mathrm{IW}}^{2(x),3(4)}$ are both zero, the nodes $C_{1.2}$ and $C_{3.4}$ would be eliminated from this chain, that could lead to $\underline{\mathrm{IW}}^{2(1),3(4)}$, $\underline{\mathrm{IW}}^{2(2),3(1)}$, $\underline{\mathrm{IW}}^{2(2),3(2)}$, and $\underline{\mathrm{IW}}^{3(4),4(1)}$ purposeless. After limiting the lower limit of integrated linkage weight, the volume of processing of nodes $C_{1.2}$ and $C_{3.4}$ would be shared individually by nodes $C_{1.1}$ and $C_{1.3}$ and nodes $C_{3.1}$, $C_{3.2}$, and $C_{3.3}$ in the distribution decision.

These results could be compared with the conventional aftermaths, which only consider one preference, of researches of cost minimization and profit maximization. According to these analytical outcomes Table 6(a) and (b) of hereinbefore two situations, the quantities of each node for processing in the plant of itself and transporting to the downstream factory would match the supplier and customers' multi-satisfactory preferences simultaneously.

6. Sensitivity analysis

With the above real world application study, the total quantities of processing for each cooperator for the afore-

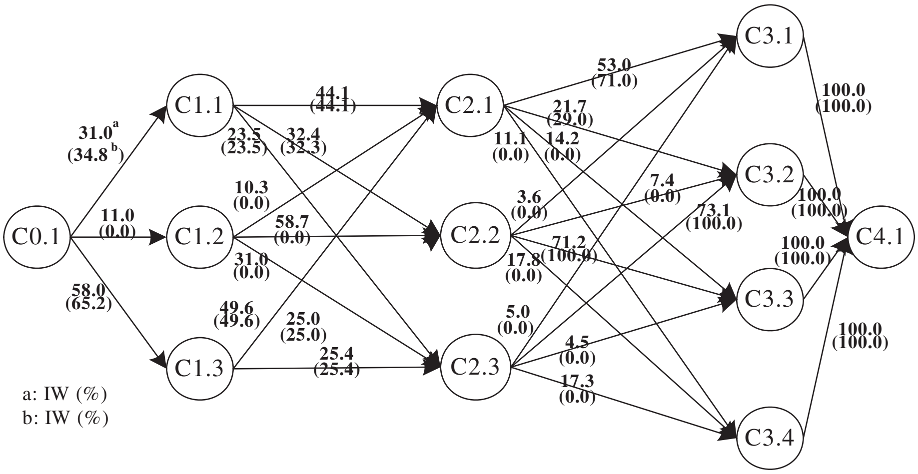

Fig. 6. Complete network for situations 1 and 2.

Table 6
Results of physical distribution by using interaction-oriented approach

		Demand										
		$C_{1.1}$	$C_{1.2}$	$C_{1.3}$	$C_{2.1}$	$C_{2.2}$	$C_{2.3}$	$C_{3.1}$	$C_{3.2}$	$C_{3.3}$	$C_{3.4}$	$C_{4.1}$
(a) Situation 1: subsistent relations must be kept												
Supply	$C_{0.1}$	310	110	580								
	$C_{1.1}$				137	100	73					
	$C_{1.2}$				11	65	34					
	$C_{1.3}$				288	145	148					
	$C_{2.1}$							231	94	62	48	
	$C_{2.2}$							11	23	221	55	
	$C_{2.3}$							13	186	12	44	
	$C_{3.1}$											255
	$C_{3.2}$											304
	$C_{3.3}$											294
	$C_{3.4}$											148
Total	310	110	580	436	310	255	255	304	294	148	1000	
(b) Situation 2: subsistent relations are not always kept and acceptable value is 0.2												
Supply	$C_{0.1}$	348	–	652								
	$C_{1.1}$				154	113	82					
	$C_{1.2}$				–	–	–					
	$C_{1.3}$				323	163	166					
	$C_{2.1}$							338	138	–	–	
	$C_{2.2}$							–	–	275	–	
	$C_{2.3}$							–	248	–	–	
	$C_{3.1}$											338
	$C_{3.2}$											386
	$C_{3.3}$											275
	$C_{3.4}$											–
Total	348	–	652	477	275	248	338	386	275	–	1000	

mentioned situations 1 and 2 are exhibited in Table 6(a) and (b), respectively. Even though, these two fundamental solutions reflected the present semiconductor supply chain distribution network where nodes $C_{1.3}$, $C_{2.1}$, and $C_{3.2}$ handle the most of scalar at respective echelon, these two mould solutions could not keep going in conferment with changes in any old cooperator's strategy for evaluating partnerships. Now, for exploring the response of solutions with possible synergetic partnership of distribution network, the sensitivity analyses would be performed by changing linkage weights. When one of integrate linkage weights in the supply chain network changes by a series of specific multipliers {0.5, 1,…,10}, the corresponding processing amount of each collaborator should be fathomed out, respectively. Fig. 7(a)–(c), with sifting $\underline{\mathrm{IW}}^{0(1),1(1)}$, $\underline{\mathrm{IW}}^{0(1),1(2)}$, and $\underline{\mathrm{IW}}^{0(1),1(3)}$, particularly, are partial demonstrations of sensitivity analyses. The potential variant boundaries of $\underline{\mathrm{IW}}^{0(1),1(1)}$, $\underline{\mathrm{IW}}^{0(1),1(2)}$, and $\underline{\mathrm{IW}}^{0(1),1(3)}$ are summarized as in the following Table 7. For $\underline{\mathrm{IW}}^{0(1),1(1)}$, in Table 7 and Fig. 7(a), a set {(0, 0.187), (0.188, 0.355), (0.356, ∞)} of the multiplier with three interval had be fathomed out, and the corresponding relationship set $\{(\underline{\mathrm{IW}}^{0(1),1(3)} > \underline{\mathrm{IW}}^{0(1),1(2)} > \underline{\mathrm{IW}}^{0(1),1(1)}), (\underline{\mathrm{IW}}^{0(1),1(3)} > \underline{\mathrm{IW}}^{0(1),1(1)} > \underline{\mathrm{IW}}^{0(1),1(2)}), (\underline{\mathrm{IW}}^{0(1),1(1)} > \underline{\mathrm{IW}}^{0(1),1(3)} > \underline{\mathrm{IW}}^{0(1),1(2)})\}$ could be derived from comparing values of $\underline{\mathrm{IW}}^{0(1),1(1)}$, $\underline{\mathrm{IW}}^{0(1),1(2)}$, and $\underline{\mathrm{IW}}^{0(1),1(3)}$. To put it another way, since the multiplier of $\underline{\mathrm{IW}}^{0(1),1(1)}$ falls on the interval from 0 to 0.187, $\underline{\mathrm{IW}}^{0(1),1(3)}$ is greater then the other two weights. Instead, $C_{1.3}$ will be the best cooperator with the $\underline{\mathrm{IW}}^{0(1),1(1)}$ is increased from 0 to 0.457. A similar pattern would be observed when other 21 weights were performed sensitivity analysis.

The priority of each cooperator will change corresponding with variant boundaries of normalized integrated linkage weights that is analyzed as aforementioned. On the score, the actual processing quantity will also shift for the specific cooperator. Now, the following sensitivity measures for 0.2 and 5 time changes in the weights either side with c (acceptable value) equals 0, 0.1, 0.2, 0.3, 0.4, and 0.5, and figures out the corresponding processing quantities. Fig. 8(a)–(d) summarize these partial results. Based on the sensitivity analysis, some inferences would be reason out as following:

1. In the complete connection statement, since either $\underline{\mathrm{IW}}$ shifts, the processing scalar of each behind cooperator will make change.
2. Since c (acceptable value) increase gradually, the number of nodes of each echelon will decrease correspondingly. While c is higher enough, there will only one node in each echelon. But, if c is too higher, the network will not efficiently implement.

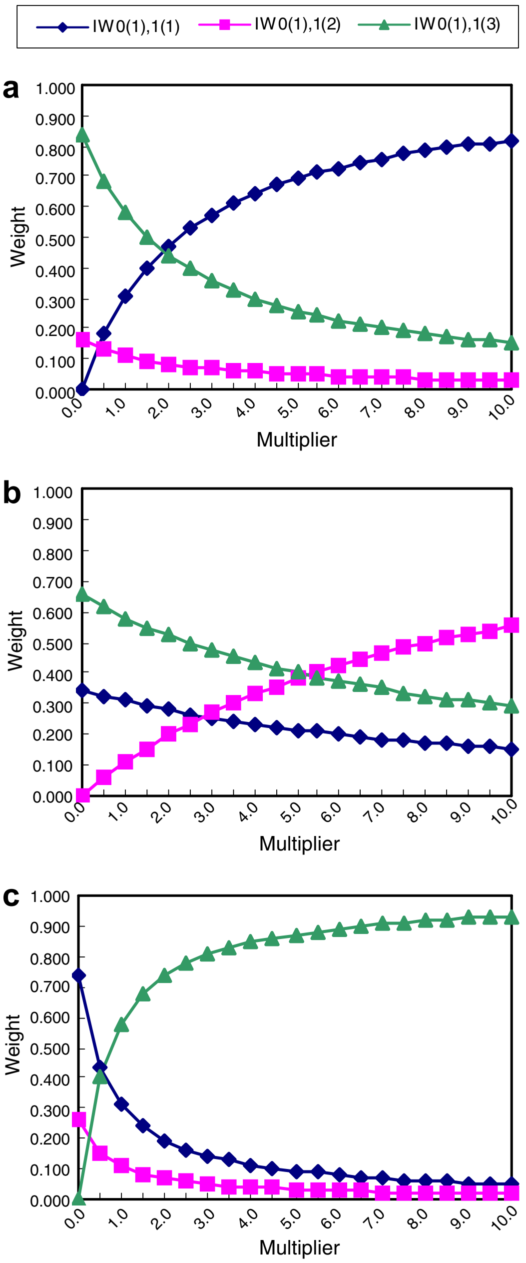

Fig. 7. Sensitivity analysis of integrate linkage weights: (a) with shifting $\underline{\underline{IW}}^{0(1),1(1)}$, (b) with shifting $\underline{\underline{IW}}^{0(1),1(2)}$, and (c) with shifting $\underline{\underline{IW}}^{0(1),1(3)}$.

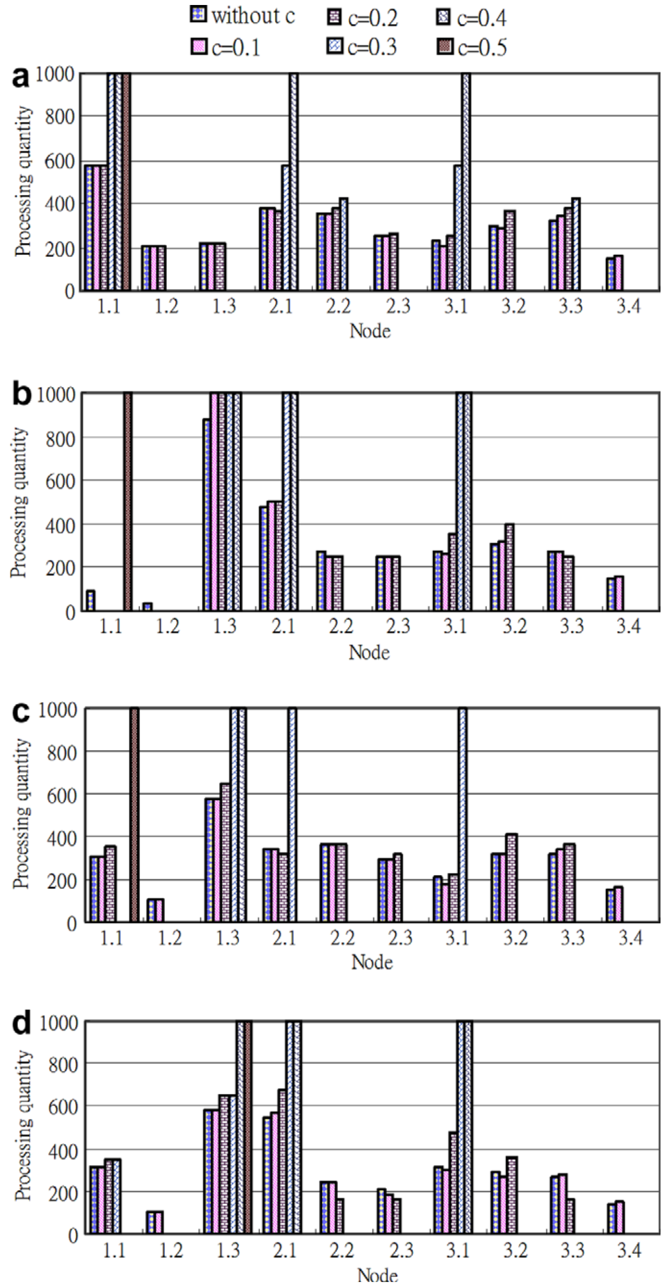

Fig. 8. Sensitivity analysis of processing quantity: (a) 0.2*$\underline{\underline{IW}}^{0(1),1(3)}$, (b) 5*$\underline{\underline{IW}}^{0(1),1(3)}$, (c) 0.2*$\underline{\underline{IW}}^{1(1),2(1)}$, and (d) 5*$\underline{\underline{IW}}^{1(1),2(1)}$.

Table 7
Partial list of sensitivity analysis of integrate linkage weights

		Multiplier of $\underline{\underline{IW}}^{0(1),1(1)}$			Multiplier of $\underline{\underline{IW}}^{0(1),1(2)}$			Multiplier of $\underline{\underline{IW}}^{0(1),1(3)}$		
		0 | 0.187	0.188 | 0.355	0.356 |	0 | 2.820	2.821 | 5.275	5.275 |	0 | 0.189	0.190 | 0.535	0.536 |
$\underline{\underline{IW}}^{0(1),1(1)}$	From	0.000	0.139	0.458	0.348	0.257	0.210	0.732	0.586	0.425
	To	0.138	0.457	1.000	0.258	0.211	0.000	0.585	0.424	0.000
$\underline{\underline{IW}}^{0(1),1(2)}$	From	0.159	0.137	0.086	0.000	0.259	0.396	0.262	0.207	0.152
	To	0.138	0.087	0.000	0.258	0.395	1.000	0.208	0.151	0.000
$\underline{\underline{IW}}^{0(1),1(3)}$	From	0.841	0.724	0.458	0.652	0.482	0.393	0.000	0.206	0.426
	To	0.725	0.457	0.000	0.483	0.394	0.000	0.207	0.425	1.000

7. Conclusions

The distribution decision is at the core of strategic supply chain network planning for semiconductor industry. This paper proposed a systematic and flexible approach to solve the complex distribution decision problem for supply chain environment efficiently and effectively. It acquires the relationships by using AHP-bases technique, which enables the inclusion of both quantitative and qualitative factors in the decision process. These factors have been decided which are based on the current business experience of the experts in the individual fields. The veritably behavior of semiconductor manufacturing process is modeled by employing interaction-oriented technique, which integrates suppliers and customers' multiple satisfactory preferences simultaneously, the quantity of shipping entities from the enterprise to it's downstream partners is decided by proportional rule and at the same time the processing quantity of entities is also figured out for each enterprise.

The presented approach discussed in this paper does not involve troublesome mathematical operation and has the ability to solve multi-factor decision making problems of supply chain design effectively. This approach is exemplified to provide a feasible quality solution and is to be applied to the real world application easily and expeditiously. In addition, it is very flexible, that permits to add more participators which locate in different geographical positions in the supply chain.

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