



# USING A MAX-MIN APPROACH TO EVALUATE THE PERFORMANCE OF A SUPPLY CLUSER NETWORK

<sup>1</sup>Travis K. Huang, <sup>2</sup>Woo-Tsong Lin

<sup>1</sup>Lecturer, Department of Information Management, Ling Tung University, Taichung, Taiwan, R.O.C.

<sup>2</sup>Professor, Management Information Systems, National Chengchi University, Taipei, Taiwan, R.O.C.

E-mail: [trunks@mail.ltu.edu.tw](mailto:trunks@mail.ltu.edu.tw), [lin@mis.nccu.edu.tw](mailto:lin@mis.nccu.edu.tw)

## ABSTRACT

With the increase in the number of studies on supply chain management practices and their application, many studies have proposed methodologies that can be used by manufacturers to evaluate vendors. These methodologies allow a buyer to choose several specific indicators or multiple criteria to evaluate vendors and distinguish them from one another based on their performance. Manufacturers can then make decisions on further cooperation with vendors who have high performance scores. Nevertheless, few studies have proposed methodologies that can be used to evaluate a supply cluster network, which consists of interlaced supply chains, as a whole. In this paper, we first apply a max-min approach and attempt to determine alternative supply chain permutations in a supply cluster network, in an effort to ascertain the preferred choice from among the supply chains in the network. We use the proposed methodology to maximize the buyer's profits under several conditions set by the buyer, and list the performance sequence of each supply chain in the supply cluster network as a whole. The results of this process can be used as criteria for future reference. Finally, we put forward suggested solutions and analytical information, and make further suggestions in relation to each individual supply chain.

**Keywords:** *Supply Chain Management, Performance Evaluation, Cluster, Supply Chain Management, Supply Network.*

## 1. INTRODUCTION

Since the end of the 20<sup>th</sup> century, due to customization and market strategies, manufacturing patterns have become more complicated. Manufacturers have devoted themselves to their areas of core competitiveness and split up their labor resources vertically or horizontally. Many manufacturers have managed to outsource other activities in the value chain one by one, thus generating supply chains. The labor division model is currently one of the critical trends in manufacturing and can allow manufacturers to reduce their production costs. In addition, enterprises need to exchange an ever-increasing volume of information to keep up with rapidly escalating demands. Enterprises in industries that fail to form clusters may be obliged to bear excess information costs.

Trends in international outsourcing, such as the adoption of OEM, EMS and ODM models, have led to reduced investment by enterprises in fixed assets such as factories and machinery, particularly since 1960. According to the transaction cost theory, if the parties to a transaction want to reduce

the risks involved in specific assets and avoid the agency problem arising from information asymmetry, the two parties will depend more on each other with regard to information sharing and exchange, but will nevertheless face high transactional information costs.

Therefore, faced with higher communication costs, industrial clusters have become one of the critical strategies used by enterprises to ensure their survival. Enterprises within the same industrial cluster acquire information at a lower cost in satisfying their quantitative and qualitative information needs.

The closer the enterprises in a cluster are to each other in geographic terms, the more available information they can acquire. Such enterprises can address the information asymmetry problem that arises in the course of the production cycle and reduce the level of uncertainty and risk they face.

The efficiency of a supply chain is based not only on the performance of the vendors as a whole, but also on the existence of a competitive and cooperative relationship between vendors. Enterprises can accelerate the flow of information



and cooperate from a technical perspective, thus resulting in further improvements to the efficiency and output of all enterprises. Efficiency is one of the critical indicators used by manufacturers when they make their decisions about orders.

In the 21<sup>st</sup> century in particular, enterprises have steadily instituted global arrangements and moved toward global logistics. At the current stage, how enterprises integrate and cooperate with their main vendors around the world and improve on the overall efficiency and output of their supply chains to enable them to respond and deliver products quickly has become one of the key criteria for survival and profitability. Therefore, competitive relationships among vendors have developed into competitive relationships between supply chains.

While many studies have explored the issues relating to supply chains, they have tended to treat supply chain management as a form of linear cooperation between upstream and downstream companies used for managing research on design and development. However, any node or particular vendor in a single supply chain is supported by its own upstream supply system, which can gradually be expanded into a "supply cluster network." A supply cluster network is composed of interlaced supply chains. From this perspective, global logistics competition in the future will inevitably evolve from competition among individual chains into competition between local supply clusters.

In this paper, based on research findings on supply chain management, we further explore the various characteristics of and issues arising from supply cluster networks..

## 2. RESEARCH PURPOSES

With the gradual maturity of studies on and the application of supply chain management, many studies have proposed methodologies that can be used to evaluate vendor performance. Manufacturers can use the indicators used in such methodologies as a reference when selecting vendors, evaluating vendors on the basis of specific indicators to learn about vendor performance and choosing to cooperate with vendors with better performance standards.

However, few studies have proposed overall performance evaluation methodologies for supply cluster networks, which are composed of or are interlaced by whole supply chains.

To address the lack of focus on this area, in this study, we present a method for determining the possible supply chain combinations within an existing supply cluster network and adopt a

methodology for evaluating the performance of such supply chains. The method used identifies the supply chain that allows a manufacturer to profit the most from a supply cluster network and to present the performance sequence for all supply chains in the same supply cluster network. When manufacturers choose a supply chain, they can use the evaluation results derived using the method we adopt as selection criteria. This paper further proposes suggested projects or indicator analysis information for each individual supply chain.

## 3. LITERATURE REVIEW

In one of his most influential studies, Porter (2000) defined an industry cluster as a geographic concentration of interconnected business, suppliers, and associated institutions in a particular field that are connected with each other by shared common points and complementary aspects. The scale of an industry cluster can range from a city to a whole state, and can even be a network of interconnected neighboring countries.

Industry clusters exhibit various patterns according to their depth and complexity. Most industry clusters include ultimate product or service vendors, professional components, parts, machinery and service vendors, financial institutions, and companies in related industries.

The extent of any international competitive advantage enjoyed by a particular country depends to a considerable extent on whether the premium industries of the relevant country can establish a so-called "industry cluster."

Carrie (2000) also referred to several industry clusters in the context of business management and technological application. For example, companies that play the role of a supplier hub are mostly logistics and multinational companies that provide supply management services for OEM companies. This kind of supplier hub model tends to restrict the development of small-scale local vendors, making it more difficult for them to acquire orders from OEM companies. Carrie also notes that supply chain management is a wide-ranging field and that the concept of an industry cluster is not usually specifically referred to in a supply chain management context.

Few experts have suggested that a network approach be adopted for a linear supply chain covering activities from material purchasing to assembly and delivery. In addition, most studies have hardly considered the roles of factors such as overall supply energy, capital, facilities and R&D



in a network. However, techniques such as groupware and e-commerce, which are currently applied to supply chain management, can also be two performance values – the max and min efficiency scores – can be calculated for each vendor.

Table 1 Various methodologies to evaluate the vendors (adapted from Talluri and Narasimhan, 2003)

Evaluation methodology	Authors
Weighted linear models	Lamberson et al. (1976), Timmerman (1986), Wind and Robinson (1968)
Linear programming	Pan (1989), Turner (1988)
Mixed integer programming	Weber and Current (1993)
Grouping methods	Hinkle et al. (1969)
Analytical hierarchy process	Barbarosoglu and Yazgac (1997), Hill and Nydick (1992), Narasimhan (1983)
Analytical network process	Sarkis and Talluri (2002)
Matrix method	Gregory (1986)
Multi-objective programming	Weber and Ellram (1993)
Total cost of ownership	Ellram (1995)
Human judgment models	Patton (1996)
Principal component analysis	Petroni and Braglia (2000)
Data envelopment analysis	Narasimhan et al. (2001), Talluri (2002a), Weber and Desai (1996), Weber et al. (1998)
Interpretive structural modeling	Mandal and Deshmukh (1994)
Game models	Talluri (2002b)
Statistical analysis	Mummalaneni et al. (1996)
Discrete choice analysis experiments	Verma and Pullman (1998)
Neural networks	Siyang et al. (1997)
Semi-structural questionnaire	Schmitz and Platts(2004)
Max-Min approach	Talluri and Narasimhan(2003)

applied to industry clusters.

Carrie referred to the concept of cluster network structures. In the process of operating the network for a whole supply system, it is particularly important to acquire and share information and knowledge. In global operation networks, in particular, enterprises should adjust their focus from company operation networks to cluster networks, and should upgrade ERP (enterprise resource planning) to CRP (cluster resource planning).

Schmitz and Platts (2004) used a semi-structured questionnaire in several locations to collect opinions and suggestions from automobile suppliers on vendor performance evaluation. In recent years, many studies have proposed methods for and suggestions on vendor performance evaluation. Talluri and Narasimhan (2003) summarized the existing methodologies for evaluating vendors, a list to which we have added a number ourselves (see Table 1).

Of the various evaluation methodologies, one proposed by Talluri and Narasimhan (2003) was the max-min approach. The main concept underlying this approach is to measure the maximum and minimum performance levels of a vendor. The vendor's performance is based on a comparison with optimal measurement standard values set by the buyer. As shown on the following page, under the three models used in the max-min approach,

In addition to ranking vendors by performance, the max-min approach also allows for the identification of vendor clusters with the same properties. Vendors allocated to the same cluster have a higher degree of homogeneity and are more likely to replace each other. In their study, Talluri and Narasimhan also suggested that whenever manufacturers have to choose an alternative vendor to replace an existing vendor, they should first consider the vendors in the same cluster. In this study, we extend the use of the max-min approach to evaluate the performance of each available supply chain in a supply cluster network.

The three models for the max-min approach are as follows:

#### Model (1)

$$\begin{aligned} \max & \frac{\sum_{r=1}^v a_r y_{r_p}}{\sum_{s=1}^u b_s x_{s_p}} \\ \text{s.t.} & \frac{\sum_{r=1}^v a_r y_{r_s}}{\sum_{s=1}^u b_s x_{s_s}} = 1, \end{aligned}$$

$$\frac{\sum_{r=1}^v a_r y_{r_i}}{\sum_{s=1}^u b_s x_{s_i}} \leq 1 \quad \forall i,$$

$$a_r, b_s \geq 0 \quad \forall r, s,$$

**Model (2)**

$$\max \sum_{r=1}^v a_r y_{r_p}$$

s.t.  $\sum_{s=1}^u b_s x_{s_p} = 1$

$$\sum_{r=1}^v a_r y_{r^*} - \sum_{s=1}^u b_s x_{s^*} = 0,$$

$$\sum_{r=1}^v a_r y_{r_i} - \sum_{s=1}^u b_s x_{s_i} \leq 0 \quad \forall i,$$

$$a_r, b_s \geq 0 \quad \forall r, s,$$

**Model (3)**

$$\min \sum_{r=1}^v a_r y_{r_p}$$

s.t. model (1) constraints are satisfied.

- p: the vendor being evaluated
- a<sub>r</sub>: the weight given to the r<sup>th</sup> output
- b<sub>s</sub>: the weight given to the s<sup>th</sup> input
- v: the number of vendor outputs
- u: the number of vendor inputs
- y<sub>ri</sub>: the value of the r<sup>th</sup> output for the i<sup>th</sup> vendor time
- x<sub>si</sub>: the value of for s<sup>th</sup> input for the i<sup>th</sup> vendor time
- y<sub>r\*</sub>: the best value for the r<sup>th</sup> output across all vendors
- x<sub>s\*</sub>: the best value for the s<sup>th</sup> input across all vendors

**4. A METHODOLOGY FOR EVALUATING THE PERFORMANCE OF SUPPLY CLUSTER NETWORKS**

In this study, we apply the methodology used in the max-min approach to evaluate the performance of each available supply chain in a supply cluster network. We first propose a method for analyzing supply cluster networks. This method involves breaking the entire supply cluster network into

several supply chains and using the max-min approach (Talluri and Narasimhan, 2003) to manage the corresponding performance evaluation of each supply chain in the network. This allows the researcher to allocate the supply chains that form part of the supply cluster network as a whole and assess the relative performance relationships among supply chains. The detailed steps to be taken under this method are as follows.

**Step 1:**

The main purpose of this step is to decompose the existing supply cluster network into several supply chains. The first step is to determine the nodes in the supply cluster network with n outcomes. For example, in Figure 1, H, I, D, F and G all have 2 outcomes. We allocate them to n. Thus, after breaking the network down, we find that we have 12 supply chains in total and we have determined the nodes in each supply chain, as shown in Figure 2 and Table 2.

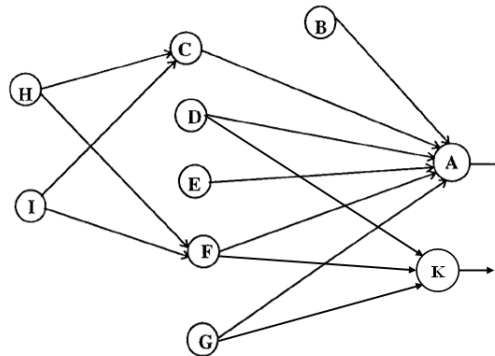


Figure 1. A supply cluster network before being decomposed

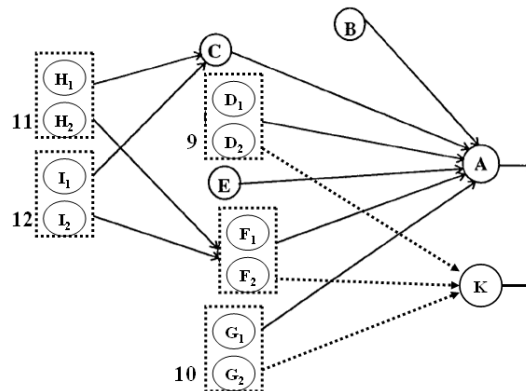


Figure 2. A supply cluster network after being decomposed



Table 2. Nodes in a supply chain

No.	Supply chain	Number of nodes
1	B - A	2
2	H <sub>1</sub> - C - A	3
3	H <sub>2</sub> - F <sub>1</sub> - A	3
4	D <sub>1</sub> - A	2
5	E - A	2
6	I <sub>1</sub> - C - A	3
7	I <sub>2</sub> - F <sub>1</sub> - A	3
8	G <sub>1</sub> - A	2
9	D <sub>2</sub> - K	2
10	G <sub>2</sub> - K	2
11	H <sub>2</sub> - F <sub>2</sub> - K	3
12	I <sub>2</sub> - F <sub>2</sub> - K	3

**Step 2:**

As stated above, the max-min approach [5] proposed by Talluri and Narasimhan (2003) is used to evaluate the performance of each vendor in a supply chain. In this study, to allow for this approach to be extended to the evaluation of the performance of each supply chain in an entire supply cluster network, we propose the three following models in which:

**Model (1)**

$$\max \frac{\sum_{p=1}^n \sum_{r=1}^v a_r y_{r_p}}{\sum_{p=1}^n \sum_{s=1}^u b_s x_{s_p}}$$

$$\text{s.t. } \frac{\sum_{r=1}^v a_r y_{r^*}}{\sum_{s=1}^u b_s x_{s^*}} = 1,$$

$$\frac{\sum_{i=1}^n \sum_{r=1}^v a_r y_{r_i}}{\sum_{i=1}^n \sum_{s=1}^u b_s x_{s_i}} \leq 1 \quad \forall i,$$

$$a_r, b_s \geq 0 \quad \forall r, s,$$

**Model (2)**

$$\max \sum_{p=1}^n \sum_{r=1}^v a_r y_{r_p}$$

$$\text{s.t. } \sum_{p=1}^n \sum_{s=1}^u b_s x_{s_p} = 1$$

$$\sum_{r=1}^v a_r y_{r^*} - \sum_{s=1}^u b_s x_{s^*} = 0,$$

$$\sum_{i=1}^n \sum_{r=1}^v a_r y_{r_i} - \sum_{i=1}^n \sum_{s=1}^u b_s x_{s_i} \leq 0 \quad \forall i,$$

$$a_r, b_s \geq 0 \quad \forall r, s,$$

**Model (3)**

$$\min \sum_{p=1}^n \sum_{r=1}^v a_r y_{r_p}$$

s.t. model (1) constraints are satisfied.

p: the supply chain being evaluated, with n nodes

a<sub>r</sub>: Weight of output at time r

b<sub>s</sub>: Weight of input at time s

v: Item for outputs of supply chain

u: Item for inputs of supply chain

y<sub>ri</sub>: output value of supply chain i at time r

x<sub>si</sub>: input value of supply chain i at time s

y<sub>r\*</sub>: optimal value of output of all supply chains at time r

x<sub>s\*</sub>: optimal value of input of all supply chains at time s

**Step 3:**

Based on the three models shown in step 2, we can calculate the maximum and minimum efficiency of each supply chain and proceed to allocate each supply chain in the supply cluster network. Supply chains with the same properties are treated as being in the same cluster. Supply chains in the same cluster can act as prior alternative replacements for each other.

**5. EXPERIMENT DESIGN AND RESULTS**

In this study, we use the supply cluster network shown in Figure 3 as an example. As shown in the figure, the supply cluster network for buyer A can be decomposed into 8 supply chains and 11 nodes in total. The H and I nodes have been broken down into four nodes (H<sub>1</sub>, H<sub>2</sub> and I<sub>1</sub>, I<sub>2</sub>) based on the principle outlined in step 1 in the previous section. In the example given in this section, each node has one evaluation value, the unit price divided by the average unit price, as an input value, and two evaluation values, which are the acceptance rate for orders dealt with and the on-time delivery rate, as output values.

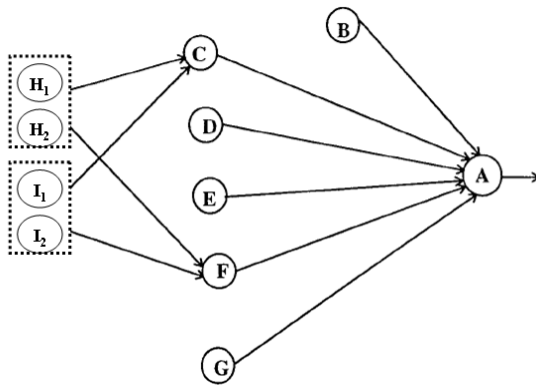


Figure 3. Example of a supply cluster network

The input and output evaluation values for each node are shown in Table 3 and are used as original data for future measurement of the performance of each supply chain.

Subsequently, in step 2, the max and min efficiency of each node are calculated using the three models for the max-min approach and are presented in Table 4. The max and min efficiency of each supply chain are then calculated, as shown in Table 5.

As can be seen from the results shown in Table 3, the optimal value of the first input is 0.8 and the optimal value of the first output is 100. The optimal value of the second output is also 100. Under this model, company A is expected to use the least resources to acquire the maximum benefits, which is the basis used for evaluations made under this model.

Arranging the max and min efficiency values for each supply chain as shown in Table 5 allows for the evaluation rankings for all chains to be calculated, as shown in Table 6. When the ranking value is lower, this indicates that the relative performance of the supply chain is better. According to Table 6, we can determine that the maximum performance value of supply chain 2 is the best. This shows that the overall “max” production capacity and performance of supply

chain 2 is rated the highest based on the evaluation indicators proposed by buyer A. However, the same supply chain is given a ranking of only 4.5 in terms of “min” production capacity and performance of the supply chain as a whole. It is ranked fourth in terms of “max” production capacity and performance of supply chain 1. Thus, its ranking is calculated as 4.5.

By contrast, looking at the ranking of supply chain 6 in Table 6, we find that in terms of overall “max” production capacity and performance, this supply chain ranks second, and that in terms of “min” production capacity and performance, it ranks third. To compare this supply chain with supply chain 2, the following points are used by company A as criteria.

First of all, in terms of the maintenance of quality standards for the long-term output of each supply chain, there is less difference between the “max” and “min” production capacity and performance levels of supply chain 6. Supply chain 6 is more likely to ensure stable overall quality. In other words, although the “max” production capacity and performance of supply chain 2 is the best, its “min” production capacity and performance, with a ranking of only 4.5, means that it is not the best supply chain when assessed on the basis of long-term quality standards. We therefore suggest that company A select the enterprises in supply chain 6 as its preferred cooperative targets; in addition, when considering short-term “max” production capacity and performance, it should choose supply chain 2. However, the latter selection should be supported by contracts or quality inspections to ensure that quality is maintained. Furthermore, company A can use other supply chains as alternative solutions or cooperate with other supply chains for parallel strategies.

If we use the max score derived using the max-min approach as X and the min score as Y, then we can obtain the distribution shown in Figure 4. This figure shows the degree of homogenous distribution among supply chains. For example, the

Table 3. Input and output values for each node

Factors	A	B	C	D	E	F	G	H <sub>1</sub>	H <sub>2</sub>	I <sub>1</sub>	I <sub>2</sub>
input	1.2	.80	.85	.98	1.24	1.3	1.15	.82	.8	.85	1.1
output1	98.8	99.2	98	97.9	100	98.8	98.8	99.2	99	97.9	98
output2	97	93	100	100	98	96	95	93	94	98.3	98

(input: unit price/average unit price; output1: acceptance; output2: on-time deliveries)

Table 4. Max and min efficiency of each node

Efficiency	A	B	C	D	E	F	G	H <sub>1</sub>	H <sub>2</sub>	I <sub>1</sub>	I <sub>2</sub>
Max. eff.	.658	.992	.941	.816	.645	.608	.687	.967	.990	.925	.714
Min. eff.	.646	.930	.922	.799	.632	.590	.660	.907	.940	.921	.712



degree of homogeneity between supply chain 6 and supply chain 2 is higher than that between supply chain 6 and supply chain 1, and the degree of homogeneity between supply chain 7 and supply chain 5 is higher than that between supply chain 7 and supply chain 8. Thus, we suggest that buyer A choose supply chain 2 as a future alternative to supply chain 6 and that it choose supply chain 5 as a future alternative to supply chain 7.

Table 5. Max and min efficiency of each supply chain

No	Supply Chain	Nodes	Max. eff.	Min. eff.
1	B - A	2	.825	.788
2	H <sub>1</sub> - C - A	3	.855	.825
3	H <sub>2</sub> - F - A	3	.752	.725
4	D - A	2	.737	.722
5	E - A	2	.651	.639
6	I <sub>1</sub> - C - A	3	.841	.829
7	I <sub>2</sub> - F - A	3	.660	.649
8	G - A	2	.672	.653

Table 6. Evaluation rankings for each supply chain under the max-min approach

No	Supply chain	Max. eff.	Min. eff.
1	B - A	4.5	6
2	H <sub>1</sub> - C - A	1	4.5
3	H <sub>2</sub> - F - A	7	9
4	D - A	8	10
5	E - A	14	16
6	I <sub>1</sub> - C - A	2	3
7	I <sub>2</sub> - F - A	12	15
8	G - A	11	13

## 6. CONCLUSIONS

In this study, we use an existing evaluation method for the vendor performance of a supply chain and attempt to evaluate the performance of each supply chain in a complicated supply cluster network to determine the best-performing supply chains. Through the max-min approach adopted in this study, alternative supply chain performance can be used as criteria for future supply chain selection decisions.

The evaluation indicators used for each node in a supply cluster network made up of interlaced supply chains should share common features. For example, unit price is not a suitable indicator for evaluation purposes. However, unit price divided by the average unit price of the relevant material can be used as an evaluation indicator in this type of analysis. The more evaluation indicators are used, the more likely it is that the performance of each supply chain can be evaluated in an objective manner. The buyer can nominate those evaluation indicators that are significant to it as measurement criteria.

Finally, the calculation method used in this study to evaluate the maximum and minimum efficiency level of each supply chain involves using the average maximum and minimum efficiency for each node in the supply chain. To improve this approach in future, the possibility of using additional statistical characteristic values or following the traditional methodology to calculate traditional network flow control should be investigated.

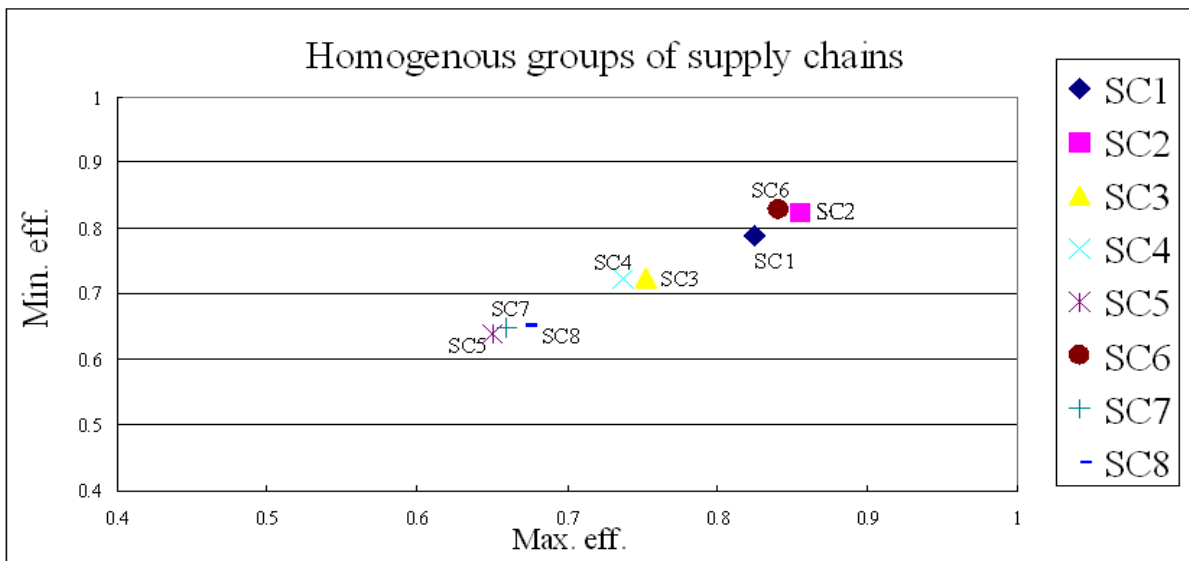


Figure 4. Homogenous groups of supply chains



## REFERENCES

- [1] Porter, Michael, "New Strategies for Inner-City Economic Development," 1997, *Economic Development Quarterly* 11(1): pp 11-27.
- [2] Porter, Michael, "The Competitive Advantage of Nations," 1990, New York: Basic Books.
- [3] Allan S. Carrie, "From integrated enterprises to regional clusters: the changing basis of competition," 2000, *Computers in Industry* 42, pp 289-298.
- [4] J. Schmitz, K.W. Platts, "Vendor logistics performance measurement: Indications from a study in the automotive industry," 2004, *Production Economics* 89, pp 231-243.
- [5] Srinivas Talluri, Ram Narasimhan, "Vendor evaluation with performance variability: A max-min approach," 2003, *European Journal of Operational Research* 146, pp 543-552