

Supplier Network Management Evaluation and Rating of Strategic Supply Networks

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ABSTRACT

Based on changing market conditions and pressure on cost and productivity, companies in different industries have started to concentrate on their core competencies and to decrease vertical range of manufacture which leads to an increasing outsourcing of business processes. With this outsourcing the dependency of companies on their business partners rises significantly forming so called value networks. Supplier Relationship Management (SRM) offers methods and tools to manage direct suppliers. In order to perform well in these value networks SRM needs to be extended towards Supply Network Management (SNM) by methods and tools to identify, evaluate, rate and select strategic suppliers located not only in tier one, but also in the subsequent tiers. The selection of adequate supply networks, satisfying different evaluation criteria, is therefore of main importance and builds the topic of this paper. The paper is based on preparatory work done in the area of strategic supply network development (SSND), where the identification of strategic supply networks has been elaborated, and focuses on the evaluation and ranking of strategic supply networks providing the base for supply network selection.

Categories and Subject Descriptors

D.2.10 [Design]: Methodologies

H.1.0 [Models and Principles]: General

H.4.2 [Types of Systems]: Logistics

General Terms

Algorithms, Management, Design

Keywords

Supplier Network Management, Evaluation, Inter-Organizational Engineering, Strategic Purchasing

1. INTRODUCTION

Changing market conditions, e.g. globalization of markets, the pressure for innovative products and mass customization, are forcing companies into an increasingly complex competitive landscape. Flexible process-oriented organizations with a strong

customer focus are essential to cope with these challenges [1;2]. Accordingly companies have to identify their core competencies in order to optimize the related processes while at the same time outsource supporting processes to business partners. Value networks spanning multiple tiers are therefore created to better fulfill specific customer requests providing customized products on time in the right quality and for a competitive price [3-6]. Corporate networks are hybrid organizational structures consisting of a fixed and a dynamic part allowing flexible extension of the network when additional competencies are needed [7]. In order to perform well in such value networks, the selection, development, management and integration of respective suppliers, located not only in tier-1 but also in the subsequent tiers, is of major relevance for gaining competitive advantages. Modern information and communication technologies – like the Internet, semantic standards, distributed applications, component based, and respectively service-oriented architectures – are necessary in order to sustain the creation and management of dynamic corporate networks [8]. Current Enterprise Resource Planning (ERP) systems build the fundamentals for the management and controlling of supply networks but there is a lack of functionality to support dynamic identification, evaluation and qualification of competent partners [7]. Even Supplier Relationship Management (SRM) Systems focusing on the interaction with suppliers concentrate primarily on direct supplier relations. The scope of the SRM systems needs therefore to be broadened especially into the area of identification, evaluation and qualification of entire value networks.

Based on previous work done in the area of identification and modeling of value networks [9-11], this paper focuses on the evaluation and rating of potential supply networks in order to support decision making for the network selection. An extension of the functionality of existing SRM systems – focusing on strategic supplier selection – to the functionality needed for modeling whole supply networks is described in chapter 2. In chapter 3 the identification of strategic supply networks and the main functionality relevant for evaluating value networks is shortly summarized. Chapter 4 describes direct supplier evaluation criteria and their impact on the evaluation of supply networks while at the same criteria examples and methods as well as a ranking mechanism is introduced. Chapter 5 provides conclusions and future work.

2. SSNM – EXTENDING SRM TOWARDS SNM

SRM provides methods, processes and tools to support the different phases of a direct supplier relationship, e.g. identification, evaluation, qualification, and if necessary

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termination [12]. Figure 1 shows an example of the task areas and functions of a SRM system (mySAP SRM) [13]). *Strategic Purchasing & Sourcing* is the process of developing a corporate supply strategy and executing it by finding qualified sources to fulfill supply needs, negotiate purchase agreements, manage contracts and evaluate supplier performance. All operational tasks and activities of purchasing are summarized in the task area *Operational Procurement*. Operational procurement is the process of buying direct materials and services (those used in production) or indirect materials and services (those used for maintenance, repair, and operations).

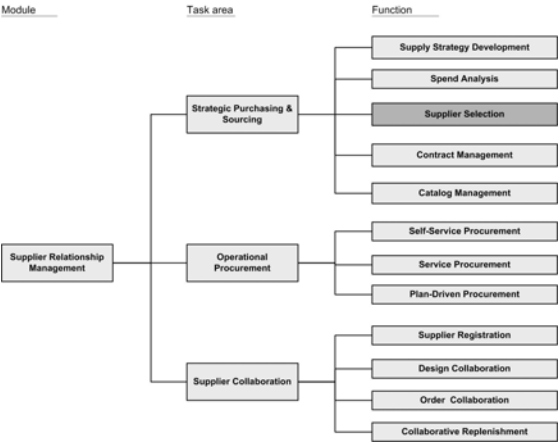


Figure 1 Task areas and functions of a SRM system

The task area *Supplier Collaboration* combines activities and tasks necessary to communicate and collaborate with suppliers. In order to perform e.g. joint product development a *Design Collaboration* can be setup with a supplier. Using these systems in practice, supplier management is widely limited to suppliers in tier-1. With respect to the increasing importance of value networks we postulate the extension of the traditional frame of reference in SRM from a supplier-centric to a supply-network-scope, i.e., the further development of the strategic supplier management to a *strategic supply network development* [9-11] and *management*. It is accomplished by replacing function *supplier selection* (as highlighted in Figure 1) with the function *strategic supply network modeling* as illustrated in Figure 2.

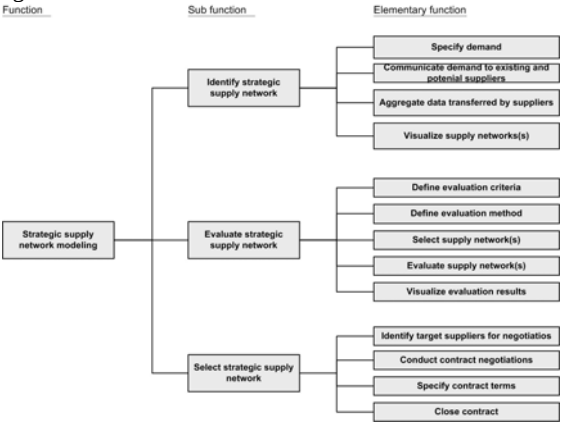


Figure 2 Functional decomposition diagram for strategic supply network modeling

The function *strategic supply network modeling* provides a methodology for the identification (*identify strategic supply network*), evaluation (*evaluate strategic supply network*) and selection (*select strategic supply network*) of potential suppliers, not only located in tier-1 but also in the subsequent tiers. For the purpose of this paper the focus is specifically set on the evaluation tasks. Since the identification of strategic supply networks builds the basis for the evaluation, we introduce shortly in chapter 3 the preparatory work done by the authors in the area of identification and modeling of strategic supply networks [9-11], before explaining in detail the evaluation criteria and methods in the next chapters.

3. IDENTIFICATION AND EVALUATION OF STRATEGIC SUPPLY NETWORKS

To model and visualize the network in a structured way, a specific strategic demand for a product to be built is communicated from the OEM to existing and/or potential suppliers. Figure 3 illustrates an example for an identification process and its results. In the example the OEM is connected to a potential network of suppliers as shown in the left part of Figure 3. It is assumed that the OEM needs to source two products externally, product 1 and product 2. During the identification process the OEM sends out demands for these products to its strategic suppliers in tier-1.

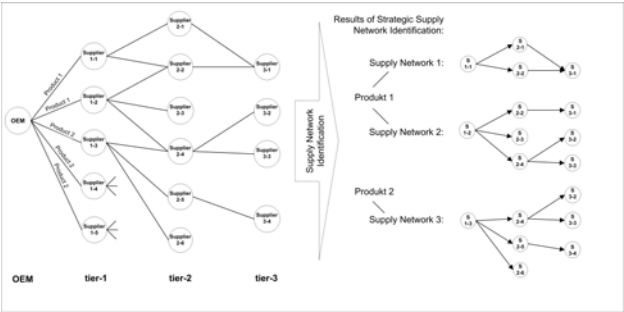


Figure 3 Example for result of identification process

In the example it is assumed that supplier1-1 and supplier1-2 get the demand for product 1 while supplier1-3, supplier1-4 and supplier1-5 receive the demand for product 2. These suppliers check whether they can fulfill the demand internally and if not sent out subsequent demands to their respective suppliers. Each node executes the same process as just described until the demand has reached the last tier. The requested information is then split lot transferred back to the OEM, aggregated and finally visualized as a supply network, in which each participant of the supply network constitutes a network hub. This process may result in the identification of several possible supply networks as shown in the right part of Figure 3, where e.g. product 1 can be provided by two supply networks, supply network 1 (root node S1-1) and supply network 2 (root node S1-2), whereas product 2 can only be provided by supply network 3. It is now up to the OEM to decide which one of the potential strategic supply networks (in the example above for product 1) will be selected to fulfill its original demand. Therefore the identified strategic supply networks are evaluated. The basic activities needed for evaluation are summarized in the functional decomposition diagram as shown in Figure 2.

As part of the *strategic supply network modeling* function the sub function *evaluate strategic supply network* consists of the elementary functions *define evaluation criteria*, *define evaluation method*, *select supply network(s)*, *evaluate supply network(s)* and *visualize evaluation results*.

Evaluation criteria may span from simple facts to highly complex considerations. One of the simplest criteria is the *minimum number of nodes* in the supply network, which can be used to minimize overall complexity of supply networks. Criteria with more extensive calculations are e.g. the *shortest total delivery time*, the *minimum total cost* or the *regional only sourcing* (indicating, that only those suppliers are selected, which are located within a certain region). Complex criteria are e.g. *maximize product quality* or *maximize delivery time liability*, since these criteria implicate the evaluation of past experience. While considering critical areas in the supply network it is also of main importance to know which nodes have absolute monopoly with their supply value or which nodes are involved in more than one potential supply network (e.g. S2-2 and S3-1 in the example in Figure 3).

After having specified the evaluation criteria the next step is to determine the evaluation method in the elementary function *define evaluation method*. The elementary function *select supply network(s)* takes the supply networks found during identification. These supply networks are evaluated and ranked within the elementary function *evaluate supply network(s)*. The result of the evaluation process is a ranking list. The supply networks on this list are visualized in the elementary function *visualize evaluation results*.

4. EVALUATION CRITERIA AND METHODS

SRM concepts and systems offer functionality for evaluating direct or tier-1 suppliers using a large variety of criteria to characterize a relationship with a supplier. These criteria can be grouped in main categories like cost, quality, time, service, relationship and organization profile [14] supporting the four dimensions of customer satisfaction being price, quality, variety and delivery [15]. Table 1 shows examples for evaluation categories and corresponding criteria.

Table 1 Examples on categories and criteria for direct supplier evaluation [14]

Category	Criteria
Cost	- Product cost - Logistics cost - Operation cost
Quality	- Product quality - Transport quality - Quality assurance
Time	- Procurement lead time - Procurement lead time liability - Product recovery time
Service	- Reaction to demand - Delivery frequency - Supply variety

While changing the view from a supplier oriented to a supply network centric focus these evaluation criteria have to be transformed into a network perspective. The transformation process is carried out by forming business objectives. From these objectives evaluation criteria are deduced which lead to

evaluation methods and algorithms respectively. Table 2 shows examples of business objectives and assigns evaluation criteria and methods to them.

In order to automate the evaluation process it is important to define algorithms as basis for software implementation.

Table 2 Examples for business objectives and evaluation criteria/methods in a supply network perspective

Business objectives	Criterion	Method
"To work with small and concise supply networks"	Number of nodes	- count number of nodes - identify minimum - select supply network
"Reduce cost of purchasing"	Cost of sourcing	- Calculate sum of sourcing per node - Summate cost for all nodes up to the root node
"Reduce procurement lead time"	Delivery time of node Transport time between nodes	- Identify paths within supply network - Calculate overall delivery and transport time per path - Identify maximum per supply network - Select supply network with minimum of total delivery time
"Ensure product quality"	Product quality factor	- Count number of bad deliveries - Calculate quality factor per node - Identify minimum quality factor for each supply network - Select supply network with highest quality factor
"Ensure liability of procurement lead time"	Procurement lead time liability factor	- Count number of out of time deliveries - Calculate procurement lead time liability factor - Identify minimum procurement lead time factor for each supply network - Select supply network with the highest procurement lead time factor

Supply networks can be treated as directed routed trees [16;17] consisting of nodes representing companies and edges representing flow of information and goods as shown in Figure 4.

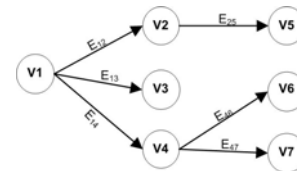


Figure 4 Example of a supply network as a directed tree

A graph G is represented by a set of nodes (V) and a set of edges (E)

$$G = (V, E) \quad (4.0)$$

As shown in Table 2 a business objective may result in multiple evaluation criteria applied to nodes and edges. Therefore we introduce an evaluation vector as illustrated in (4.1).

The elements of this vector represent criteria and indicators e.g. *cost of purchasing* (c_i, c_{ij}), *procurement lead time* (t_i, t_{ij}), *product quality factor* (q_i, q_{ij}), *procurement lead time liability* (p_i, p_{ij}). ec_{Vi} is the evaluation vector for a node and ec_{Eij} the evaluation vector for an edge. This paper describes five example criteria and the related methods (algorithms, calculation schema) and suggests a ranking process in order to select supply networks based on a combination of criteria.

$$\alpha_{v_i} = \begin{pmatrix} c_i \\ t_i \\ p_i \\ \dots \end{pmatrix} \quad \alpha_{e_{ij}} = \begin{pmatrix} c_{ij} \\ t_{ij} \\ p_{ij} \\ \dots \end{pmatrix} \quad (4.1)$$

Number of nodes

The evaluation of a supply network (G) using the number of nodes ($n(G)$) criterion is implemented by the following algorithm:

$$n(G) = |V(G)| \quad (4.2)$$

This algorithm simply counts the number of nodes of the supply network.

Cost of purchasing

While calculating the cost of purchasing ($c(G)$) it is assumed that there is a cost element related to a node (cn_{v_k}) (e.g. production cost) and a cost element which is related to an edge (ce_{e_k}) (e.g. transportation cost). The cost of purchasing is the sum of all these cost elements:

$$c(G) = \sum (cn_j + ce_e) \quad (\forall j, k : j \in V, k \in E) \quad (4.3)$$

Procurement lead time

The procurement lead time consists of time elements of nodes (tn_{v_k}) (e.g. production time or delivery time) and time elements of edges (te_{e_k}) (e.g. transport time). In order to calculate the maximum procurement lead time for the complete supply network each node (which is not an end node) has to calculate the maximum procurement lead time of all out-tree paths. Being $N_G(k)$ all adjacent neighbors of node k the procurement lead time (t_k) of node k is the sum of the internal node lead time (tn_k) and the maximum of the procurement lead times of all adjacent neighbor nodes (being E_{kj} the edges connecting node k with its adjacent neighbor nodes):

$$t_k(G) = tn_k + \max \{ (te_{E_{kj}} + t_j) : j \in N_G(k) \} \quad (4.4)$$

This calculation scheme can be repeated for each node in the tree. The overall procurement lead time of the supply network can be calculated setting $k = 1$ (being 1 the root node of out-tree G).

Product quality and procurement lead time liability

In the context of evaluating supply networks *product quality* describes the ability of a supplier to deliver good products. For the purpose of this paper good products are defined as products which are acceptable for further usage while bad products are products which are not usable and which need to be replaced. In most cases replacing products directly affect procurement lead time negatively as well. Therefore it is desirable that the number of bad products a supplier delivers is as low as possible. In order to use product quality as evaluation criteria for a supply network a *product quality factor* (q) is introduced. This *product quality factor* refers to the relationship between two nodes and is based on historical data of deliveries.

As described earlier in this chapter the procurement lead time is used as criterion for the evaluation of supply networks. Working with supply networks there can be situations where a certain node is not able to adhere to the procurement lead time originally forecasted, e.g. because of bad product quality. Hence it is important to know the liability of the procurement lead time forecasted by the supply network. Therefore the *procurement lead time liability factor* (p) is introduced. This factor indicates the ratio of number of deliveries within the forecasted procurement lead time to the total number of deliveries. This factor also refers

to the relationship between two nodes and is computed analyzing historical data of deliveries. Both factors are calculated as:

$$q = \frac{\text{number of good product deliveries}}{\text{number of all deliveries}} \quad (4.5a)$$

$$p = \frac{\text{number of deliveries within procurement lead time}}{\text{number of all deliveries}} \quad (4.5b)$$

It is desirable to have the *product quality factor* and the *procurement lead time liability factor* as close as possible to 1. For the purpose of this paper the influences of nodes and edges are combined.

The calculation for the *product quality factor* and *procurement lead time liability factor* respectively is executed within every node in the supply network for all adjacent neighbor nodes. It is obvious that in a supply network scenario a node will normally have more than one adjacent neighbor nodes. Therefore a *factor table* is introduced at every node. Based on the supply network example illustrated in Figure 4 an example of the *factor table* for node $V1$ is shown in Table 3.

Table 3 Example for a factor table on node $V1$

$V1$	q	p
$V2$	0,85	0,95
$V3$	0,93	0,93
$V4$	0,91	0,89

The *product quality factor* for node $V1$ is calculated based on the entries in this table. It is assumed that the lowest *product quality factor* in the table is determining the overall *product quality factor* of node $V1$. Therefore the minimum value is extracted from the product quality factor table. In the example above the *product quality factor* for $V1$ is $q_1 = 0,85$.

The same assumptions are made for the calculation of the *procurement lead time liability factor*. In the example above the *procurement lead time liability factor* for $V1$ is $p_1 = 0,89$.

Forming a more generic calculation scheme the following is suggested: Being $N_G(k)$ all adjacent neighbors of node k the *product quality factor* q_k and the *procurement lead time factor* p_k are calculated as:

$$q_k = \min \{ q_j : j \in N_G(k) \} \quad (4.6a)$$

$$p_k = \min \{ p_j : j \in N_G(k) \} \quad (4.6b)$$

The overall *product quality factor* of the supply network is calculated by forming the minimum of the *product quality factor* of all nodes assuming that the lowest *product quality factor* of a node is determining the *product quality factor* of the supply network. The same approach is used for the *procurement lead time liability factor* of the supply network:

$$q(G) = \min \{ q_k : k \in V(G) \} \quad (4.7a)$$

$$p(G) = \min \{ p_k : k \in V(G) \} \quad (4.7b)$$

Combinations of criteria

Using the methods introduced above it is possible to form a total evaluation vector (e_i) for each supply network (G_i).

$$e_i = \begin{pmatrix} en_i \\ ec_i \\ et_i \\ eq_i \\ ep_i \end{pmatrix} \quad (4.8a)$$

With

$$en_i = n(G_i); ec_i = c(G_i); et_i = t_l(G_i); eq_i = q(G_i); ep_i = p(G_i) \quad (4.8b)$$

The identification process may find m valid supply networks ($G(i): i = \{1, \dots, m\}$) all able to fulfill the original demand. Therefore the evaluation process needs to compare m evaluation vectors in order to select the supply network, which meets the evaluation business objective best. The evaluation business objective may be based on a single criterion (e.g. "min. number of nodes") but could also be a combination of criteria (e.g. "min. cost of purchasing and min. procurement lead time"). The combination of criteria can be handled by introducing a weight vector.

$$w = \begin{pmatrix} wn \\ wc \\ wt \\ wq \\ wp \end{pmatrix} \quad (4.9)$$

This allows the OEM to prioritize criteria, e.g. $w = \{1, 0, 0, 0, 0\}$ means "min. number of nodes" or $w = \{0, 0.5, 0.5, 0, 0\}$ means "min. cost of purchasing and min. procurement lead time".

The evaluation criteria have different dimensions. Number of nodes, purchase cost and procurement lead time are values whereby product quality and procurement lead time liability are factors. Therefore it is necessary to introduce a scaling of values in order to achieve comparable factors. All factors in the evaluation vector are then multiplied with the weight vector. This process is repeated for all m supply networks ending in a ranking list ($r_i(G): i = \{1, \dots, m\}$):

$$r_i(G) = \left(wn \times \frac{en_{\min}}{en_i} \right) + \left(wc \times \frac{ec_{\min}}{ec_i} \right) + \left(wt \times \frac{et_{\min}}{et_i} \right) + wq \times eq_i + wp \times ep_i \quad (4.10a)$$

$$en_{\min} = \min \{ en_i : i \in \{1, \dots, m\} \} \quad (4.10b)$$

$$ec_{\min} = \min \{ ec_i : i \in \{1, \dots, m\} \} \quad (4.10c)$$

$$et_{\min} = \min \{ et_i : i \in \{1, \dots, m\} \} \quad (4.10d)$$

The ranking list is then sorted in descending order having the supply network at position 1, which meets the evaluation business objective best. It is now up to the OEM to decide, whether the top ranked supply network is selected for purchasing or whether, as in real world scenarios, the demand is split and purchasing is done with e.g. the top two ranked supply networks.

5. CONCLUSION AND FUTURE WORK

The domain of supplier relationship management is facing drastic changes while introducing a supply network perspective. It is important to find the adequate suppliers to form these so called value networks. In order to select the respective supply networks they need to be identified and evaluated. Based on preparatory work done in the area of identification and modeling of strategic supply networks, this paper provides algorithms based on vectors containing different evaluation criteria reflecting the relevant business objectives. Because of different possible combinations of criteria weights are introduced for each evaluation criteria and a scaling of values is performed in order to provide a ranking list necessary for the selection of the best supply network.

Future work needs to extend the evaluation category and criteria list for supply networks. Furthermore additional work is necessary in the area of identifying critical nodes and critical paths within supply networks in order to optimize the supply networks and minimize risk of purchasing.

6. REFERENCES

- [1] Burtler, P., et al., *A Revolution in Interaction*. The McKinsey Quarterly, 1997. 1/97: p. 4-23.
- [2] Österle, H., *Business Engineering - Prozeß- und Systementwicklung: Entwurfstechniken*. 2 ed. Vol. 1. 1995, Berlin: Springer.
- [3] Malone, T.W. and R.J. Lautbacher, *The Dawn of the E-Lance Economy*. Harvard Business Review, 1998(September-October): p. 145 - 152.
- [4] Warnecke, H.-J., *Vom Fraktal zum Produktionsnetzwerk. Unternehmenskooperationen erfolgreich gestalten*, ed. J.H. Braun. 1999, Berlin.
- [5] Pine, B.J., B. Victor, and A.C. Boynton, *Making Mass Customization Work*. Harvard Business Review, 1993. 36(5): p. 108-119.
- [6] Tapscott, D., D. Ticoll, and A. Lowy, *Digital Capital: Harnessing the Power of Business Webs*. 2000, Boston.
- [7] Angeli, R. *Aufbau und Koordination dynamischer Unternehmensnetzwerke*. in *Wissenschaftssymposium Logistik der BVL*. 2002: Huss Verlag.
- [8] Kopanaki, E., et al. *The Impact of Inter-organizational Information Systems on the Flexibility of Organizations*. in *Proceedings of the Sixth Americas Conference on Information Systems (AMCIS)*. 2000. Long Beach, CA.
- [9] Albani, A., et al. *Component Framework for Strategic Supply Network Development*. in *8th East-European Conference on Advances in Databases and Information Systems (ADBIS-04)*, LNCS 3255. 2004. Budapest, Hungary: Springer Verlag.
- [10] Albani, A., et al. *Dynamic Modelling of Strategic Supply Chains*. in *E-Commerce and Web Technologies: 4th International Conference, EC-Web 2003 Prague, Czech Republic, September 2003*, LNCS 2738. 2003. Prague, Czech Republic: Springer-Verlag.
- [11] Albani, A., C. Winnewisser, and K. Turowski. *Dynamic Modelling of Demand Driven Value Networks*. in *On The Move to Meaningful Internet Systems and Ubiquitous Computing 2004: CoopIS, DOA and ODBASE*, LNCS. 2004. Larnaca, Cyprus: Springer Verlag.
- [12] Eyholzer, K., W. Kuhlmann, and T. Münger, *Wirtschaftlichkeitsaspekte eines partnerschaftlichen Lieferantenmanagements*. HMD - Praxis der Wirtschaftsinformatik, 2002. 39(228): p. 66-76.
- [13] SAP, *SAP Company Information: mySAP Supplier Relationship Management Solution Map*. 2004, SAP AG.
- [14] Ellram, L.M., *The Supplier Selection Decision in Startegic Partnerships*. Journal of Purchasing and Materials Management, 1990. 26(1): p. 8-14.
- [15] Tracey, M. and C.L. Tan, *Empirical analysis of supplier selection and involvement, customer satisfaction and firm performance*. Supply Chain Management: An International Journal, 2001. 6(4): p. 174-188.
- [16] Jungnickel, D., *Graphs, networks and algorithms*. Vol. 2. 2005, Berlin: Springer.
- [17] Ahuja, R., T. Magnanti, and J.B. Orlin, *Network flows: Theory, algorithms and applications*. 1993, New Jersey: Prentice-Hall.