Route Selection in a Dynamic Multi-Agent Multilayer Electronic Supply Network

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Abstract

We develop an intelligent information system in a multilayer electronic supply chain network. Using the internet for supply chain management (SCM) is a key interest for contemporary managers and researchers. It has been realized that the internet can facilitate SCM by making real time information available and enabling collaboration between trading partners. Here, we propose a multi-agent system to analyze the performance of the elements of a supply network based on the attributes of the information flow. Each layer consists of elements which are differentiated by their performance throughout the supply network. The proposed agents measure and record the performance flow of elements considering their web interactions for a dynamic route selection. A dynamic programming approach is applied to determine the optimal route for a customer in the end-user layer.

Keywords : Electronic Supply Chain Management (e-SCM), Route Selection, Information System, Intelligent Agents

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1. Introduction

Business environment is becoming increasingly complex, uncertain, unpredictable, and as a result, more and more competitive. As competition being intensified, flexibility-based supply chain management (SCM) is emerging as an increasingly important issue for companies [Hewitt, 1994; Mills, et al., 2004]. The challenge of flexibility in SCM is to identify and implement strategies to minimize cost while enhancing flexibility in an increasingly competitive and complex market [Browne, et al., 1997; Wadhwa and Saxena, 2005]. Flexibility stands out as a prominent applicable element in manufacturing and supply chains (SCs) [Browne, et al., 1995; Chan, et al., 2006; Stecke and Solberg, 1981]. [Sushil, 2000], while deliberating upon the concept of systematic flexibility, has essentially stressed the multiplicity of connotations of flexibility in response to diversity of situations. [Wadhwa and Rao, 2000] defined flexibility as the ability to deal with change by judiciously providing and exploiting controllable options dynamically. The potential of certain types of flexibility to enhance the overall performance of manufacturing and supply chain system has attracted the attention of many researchers (for examples, see [Browne, et al., 1984; Chan, et al., 2004; Wadhwa, et al., 2005]. The effects of flexibility on the performance of an SC need to be more closely studied as scholars are having diverse interpretations [Cousins, 2005].

Enhanced competitiveness requires that companies ceaselessly integrate within a network of organizations [Romano, and Vinelli, 2001]. Firms ignoring this challenge are destined to fall behind their rivals. The integration of companies within a network demands a new look at the supply chain management (SCM) [Danese, et al., 2006]. "SCM is the management of upstream and downstream relationships in order to deliver superior customer value at less cost to the supply chain as a whole" [Christopher, 1998]. The integral value of the SCM philosophy is that the total performance of the entire supply chain is enhanced when we simultaneously optimize all the links in the chain as compared to the resulting total performance when each individual link is separately optimized [Burke and Vakkaria, 2002].

Recent technological developments in information systems and information technologies have the potential to facilitate the coordination, and this, in turn, allows the virtual integration of the entire supply chain. The focus of this integration in the context of internet-enabled activities is generally referred to as electronic SCM (e-SCM). Merging SCM and the internet is a key area of concern for contemporary managers and scholars [Cagliano, et al., 2003]. Managers realize that the internet can enhance SCM decision making by providing real-time information and enabling collaboration between trading partners. Many companies have implemented point-of-sales scanners, which read, in real time, what is being sold. These companies not only collect information in real-time to make decisions about what to order or how to replenish the stores, but they also send the information, through the internet, to their suppliers to help them synchronize their productions to actual sales.

Following the definition of SCM in [Cooper, et al., 1997], we define e-SCM as the impact of the internet on the integration of key business processes from end-user through original suppliers providing products, services and information that add value for customers and other stakeholders. The main objective of our work here is first to identify the major issues concerning the impact of the internet on SCM, while focusing on supply chain processes, and then offer an integrated supply network associated with the corresponding layers and elements to provide an optimal route.

As pointed out in [Croom, 2005], there is some debate about the scope of SCM. For example, in [Houlihan, 1984; Oliver and Webber, 1992] the authors used the term SCM for the internal supply chain integrating business functions involved in the flow of materials and information from inbound to outbound ends of the business. [Ellram, 1991] viewed SCM as an alternative to vertical integration. [Cooper, et al., 1997] defined SCM as "the integration of key business processes from end-user through original suppliers that provides products, services, and information that add value for customers and other stakeholders". And, [Christopher, 1998] defined SCM as the management of upstream and downstream relationships. Croom [Croom, 2005] suggested that one way of dealing with the diversity of SCM definitions was to concentrate on the core processes and functions relating to the management of supply chains (for example, fulfillment, operations planning and procurement).

Here, we consider a five layer supply chain network including supplier, manufacturer, distributor, retailer, and customer. In each layer, we propose a corresponding intelligent agent in a virtual environment through the internet. Our aim in proposing such an agent based system is to analyze the performance and identify an optimal route in the network, making use of the information flow.

2. Intelligent Agents

An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors. A robotic agent substitutes cameras and infrared range finders for the sensors and various motors for the effectors. A software agent encodes bit strings as its percepts and actions.

According to the definitions given before previous sections, each component of a supply chain (SC) is involved in various activities such as planning and controlling stock, quality control, procurement, marketing, relationship with customers, sale, distribution, etc. Therefore, considering multi agent system definitions and concepts, an SC can be considered as a multi agent system in which each element of the chain has the nature of an agent.

Generally speaking, agents are active, persistent (software) components with the abilities of perceiving, reasoning, acting and communicating [Fung, et al., 2005]. The agent may follow a set of rules predefined by the user and then apply them. The intelligent agent will learn and will be able to adapt to the environment in terms of user requests consistent with the available resources

[Papazoglou, 2001]. The key aspects of agents are their autonomy and abilities to reason and act in their environment, as well as to interact and communicate with other agents to solve complex problems [Jain, et al., 1999]. Autonomy means that the agent can act without direct intervention of humans or other agents and that it has control over its own actions and internal state. The agent communicates with the user and/or other agents to receive instructions and provide results. Essential qualities of an agent are the amount of learned behavior and possible reasoning capacity that it has.

As the market needs are widely diverse and fashions update quickly, a supply chain member cannot usually make decisions instantly because of the inaccurate or incomplete information at hand. Decision delay in a supply chain prolongs the processing time, causing loss of competence for a company. To reduce delay, a supply chain member needs to respond quickly. Thus, a supply chain can be characterized as a logistic network of partially autonomous decision-makers. Supply chain management has to do with the coordination of decisions within a network. Different segments of a network communicate with one another through flows of material and information, while being controlled and coordinated by the activities of the supply chain management.

3. The Proposed Model of Multilayer e-SCM

Here, we describe a multilayer agent based electronic supply network. As stated before, the proposed network consists of five layers (see <Figure 1>). At one layer, suppliers provide raw materials for factories to make a product and present it at the markets. All suppliers present their goods in their web sites and manufacturers collect the information about the suppliers by visiting the websites. Then, using the proposed intelligent agent, the ranking of suppliers, data analysis and data saving are performed.

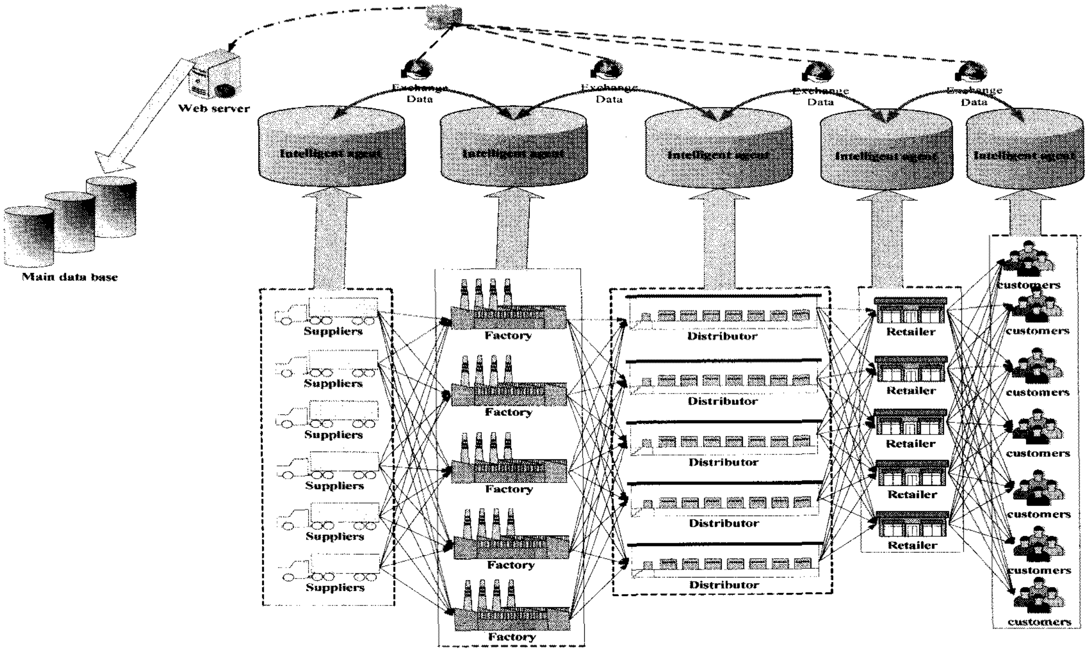
The next layer is for manufacturers. Manufacturers exchange their manufacturing data with one other through the World Wide Web. The data are collected and analyzed via an intelligent agent. The intelligent agent works out to be a decision aid and provides information about vehicles, production processes, depot analysis and optimization, and manufacturing optimization. The results are saved in the corresponding data base and viewed for public visit in an internet web site. The third and fourth layers are distributors and retailers. Here, interaction between distributor and retailer is allowed. Distributors share their depot information, due dates, order list, etc., in the internet using an information sharing mechanism. The vehicles of distributors are connected to a server and report real time information about the delivery of products to retailers. Retailers' interests, needs and orders are specified in their corresponding web sites, deposited in a data base.

The intelligent system collects the information from different servers, analyzes them and provides a report containing orders in transit, orders delivered, orders sent and the distributor depot inventory control. The last layer of the proposed multilayer SCM is composed of customers having interactions with retailers. Customers present their interests and needs in a local server. The data are saved in the market data bases and transferred to the World Wide Web. At the same time, retailers show their products and their specifications in another local server, and then transfer them to the retailer data base. The intelligent agent collects the information from both sides and helps retailers in decision making about the customer relationship management through the web and electronic quality function deployment. For customers, the decisions may concern modifying the interests due to product specifications, and procurement through the web.

Considering the interactions amongst elements of the proposed multilayer e-SCM, an intelligent agent exists which flows the information and exchanges data between any two layer. Here, we develop a new methodology for the integration of elements in different layers. The aim of the integration is to improve the serviceability of the network and increase the flexibility in presenting multi commodity markets' network. As the configuration of our proposed intelligent agent based SCM in <Figure 1> shows, intelligent agents record and trace the data transfer and exchange between and within the layers. All the information are deposited in a main data base. The route selection is performed using the data of the main data base.

4. Information Flow Interaction in e-SCM

The interaction between any two elements of the multilayer SCM depends on time periods. The information flow is different in dif-



〈Figure 1〉 A configuration of the proposed intelligent agent based SCM ferent time periods, and thus we need to take time into account. We consider the information flow between any two elements as some attributes affecting the interactions. A configuration of the interaction among elements is presented in <Figure 2>. Considering that the information sharing takes place among all the elements in different layers, any element in a layer is considered to get a score in relation to the elements in the preceding layer with respect to the knowledge gained from information sharing. The mathematical notations are now presented.

- Mathematical notations :

I Index for element in a layer; $i = 1, \cdots, I$.

j Index for element in a subsequent layer; $j = 1, \cdots, J$.

t Index for time period; $t = 1, \cdots, T$.

m Index for attribute; $m = 1, \cdots, M$.

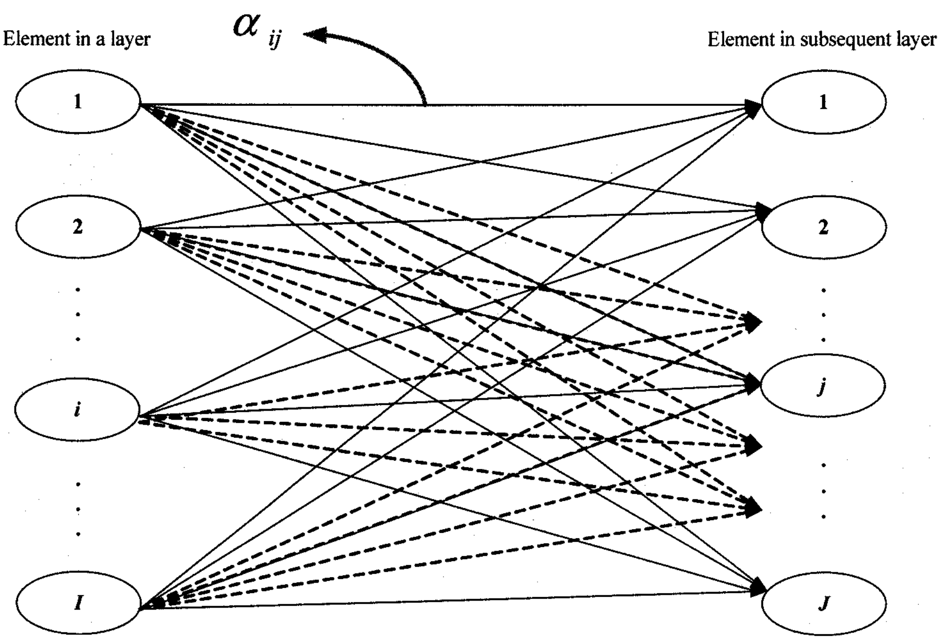
A_m The m^{th} attribute.

α_{ij} The score of interaction between i^{th} element in a layer with j^{th} element in the subsequent layer.

S^{it} Matrix with S^{it}_{jm} values for interactions α_{ij} with attributes m (extracted from <Table 1>), for $j = 1, \cdots, J$, $m = 1, \cdots, M$ ($i = 1, \cdots, I$, $t = 1, \cdots, T$).

Considering the above notations, the matrix in <Table 2> is configured for scores of interactions with respect to attributes. In this matrix, we consider a numerical preference value chosen from <Table 1>, for each interaction with respect to an attribute.

Note that the scores presented in <Table 2> are only related to the time period 1 and the



〈Figure 2〉 A configuration of the interaction between elements interaction is between two layers; for other time periods and other pairs of layers, the same scoring process is performed (the same applies to <Table 3> and <Table 4> as well). A process of scoring in different time periods and the continuous improvement are depicted in <Figure 3>. As depicted in <Figure 3>, the interactions among elements of two sequential layers are computed using the proposed matrices and gathered via an intelligent agent and transferred to the data base in one period. Due to weaknesses of the supply network resulting from the computations, modifications are performed in the next period. The dynamic structure is continued till the end of the periods.

To obtain the α values considering the attributes, a normalization process is performed as follows :

$$\bar{S}^{it}_{jm} = \frac{S^{it}_{jm}}{\sqrt{\sum_{k=1}^{J} (S^{it}_{km})^2}}$$

where $\bar{S}^{it}_{jm}$ is the normalized vector for S_{jm}. Using the normalized values, we can configure the normalized table <Table 3>.

Since the weight of an attribute should be based on the decision maker's interest and its own significance, we multiply the values in <Table 3> by a weight coefficient β_m for the m^{th} attribute, with $\sum_{m=1}^{M} \beta_m = 1$, which is given by decision maker. Thus the weighted table is configured as <Table 4>.

Computing the arithmetic mean corresponding to the rows in <Table 4>, we obtain the corresponding α values. Hence, we configure an *element-to-element* matrix which is being filled with the normalized weighted values of α

〈Table 1〉 ARC Preferences with their numerical values

Preference	Numerical value
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1
Preferences in between the above preferences	2, 4, 6, 8

〈Table 2〉 Interaction scoring

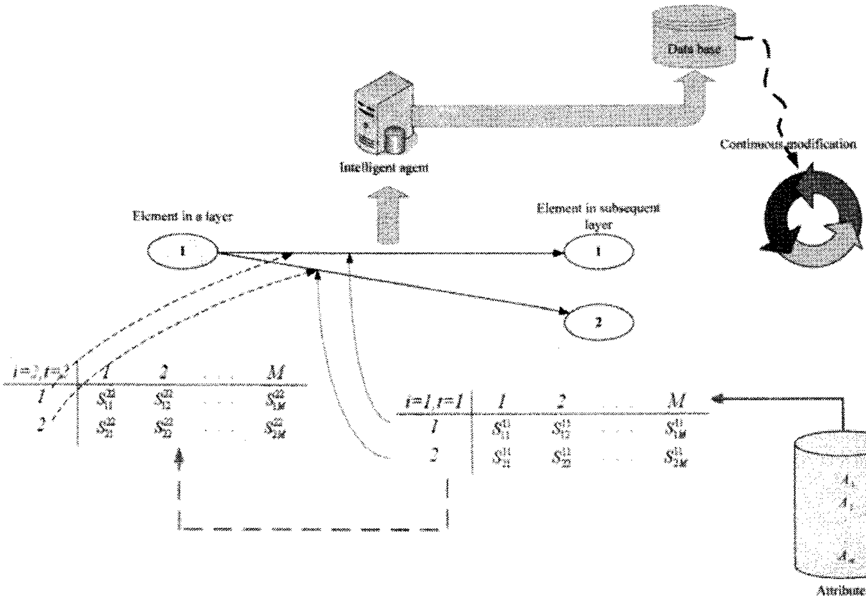
$i=1,\ t=1$	1	2	$\cdots$	M
1	S^{11}_{11}	S^{11}_{12}	$\cdots$	S^{11}_{1M}
2	S^{11}_{21}	S^{11}_{22}	$\cdots$	S^{11}_{2M}
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
J	S^{11}_{J1}	S^{11}_{J2}	$\cdots$	S^{11}_{JM}

〈Table 3〉 The normalized values

$i=1,\ t=1$	1	2	$\cdots$	M
1	$\bar{S}^{11}_{11}$	$\bar{S}^{11}_{12}$	$\cdots$	$\bar{S}^{11}_{1M}$
2	$\bar{S}^{11}_{21}$	$\bar{S}^{11}_{22}$	$\cdots$	$\bar{S}^{11}_{2M}$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
J	$\bar{S}^{11}_{J1}$	$\bar{S}^{11}_{J2}$	$\cdots$	$\bar{S}^{11}_{JM}$

〈Table 4〉 The weighted scores

$i=1,\ t=1$	1	2	$\cdots$	M
1	$\beta_1 \cdot \bar{S}^{11}_{11}$	$\beta_2 \cdot \bar{S}^{22}_{11}$	$\cdots$	$\beta_M \cdot \bar{S}^{11}_{1M}$
2	$\beta_1 \cdot \bar{S}^{11}_{21}$	$\beta_1 \cdot \bar{S}^{11}_{22}$	$\cdots$	$\beta_M \cdot \bar{S}^{11}_{2M}$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
J	$\beta_1 \cdot \bar{S}^{11}_{J1}$	$\beta_1 \cdot \bar{S}^{11}_{J2}$	$\cdots$	$\beta_M \cdot \bar{S}^{11}_{JM}$



〈Figure 3〉 A process of scoring in different time periods and the continuous improvement

〈Table 5〉 The element-to-element scores

$t = 1$	element	element	⋯	element
element	α_{11}	α_{12}	⋯	α_{1J}
element	0	α_{22}	⋯	α_{2J}
⋮	0 0 0	0 0 0	⋮	⋮
element	0	0	⋯	α_{1J}

(see <Table 5>). Each element in the table corresponds to a preceding layer and the one immediately after.

We use a threshold value to evaluate the quality of the obtained α scores. The proposed threshold is Z_p; i.e., the p^{th} percentile of standard normal distribution. Next, we describe the proposed threshold.

4.1 Element Scoring Threshold

Here, we discuss a threshold value applied to assess the scores obtained for each interaction. The aim of using the threshold is to improve the performance of the proposed SCM. The threshold helps identifying the weaknesses between interactions of any two layers in the proposed network. Assume that α_{ij} is the score of each interaction for each i^{th} element in any layer. Then μ_{io} and σ_{io} are mean and standard deviation of scores between any pairs of layers for one element, respectively. Thus, we have,

$$\mu_{io} = \frac{\sum_{j=1}^{J} \alpha_{ij}}{J}, \quad i = 1, \cdots, I,$$

$$\sigma_{io} = \sqrt{\frac{\sum_{j=1}^{J} (\alpha_{ij} - \mu_{io})^2}{J-1}}, \quad i = 1, \cdots, I,$$

where J is the number of interactions for one element (or elements of subsequent layer).

Applying the mean and standard deviation, we define the proposed threshold value as follows :

$$Z_{ij} = \frac{\alpha_{ij} - \mu_{io}}{\frac{\sigma_{io}}{\sqrt{J}}}$$

For any confidence level, we can decide upon the appropriateness of α using the proposed threshold value Z. For instance, if the confidence level is 95%, then using standard normal distribution tables we obtain $Z_{95\%} = 1.96$, and thus any value of α lower than 1.96 is considered to be inappropriate and hence omitted from the process.

As a result, the intelligent agent omits the α values lower than Z. Then, using the remaining α values, we determine the optimal route in the multilayer network for the customer using a backward dynamic program. The details of the proposed dynamic program are given in the next section.

4.2 A Dynamic Program for the Optimal Route

Dynamic programming is a technique widely used for multistage decision processes. A given problem is subdivided into smaller subproblems, which are sequentially solved until the original problem is solved by the aggregation of the subproblem solutions. The optimality principle states that an optimal policy should be constituted by optimal policies from every state of the decision chain to the final state. Here, we make use of a dynamic programming approach in our proposed network to identify the optimal route for the customers or any other element of the multilayer SCM. The dynamic model would be defined as follows here.

- Indices :

n Number of layer ; $n = 1, 2, 3, 4, 5$.

i Start node number corresponding to a layer ; $i = 1, 2, \cdots, I$.

j End node number corresponding to subsequent layer ; $j = 1, 2, \cdots, J$.

- Notations :

$\phi_n(i)$ The maximum value of moving from an element i in a layer n to an element j in layer $n+1$.

α_{ij} Numerical value of an arc between two elements.

- Optimal policy :

$$\varphi_n(i) = \underset{j \text{ in layer } n+1}{Max} \{\varphi_{n+1}(j) + \alpha_{ij}\}$$
$$n = 1, 2, 3, 4, \ \forall i \text{ in layer } n$$

Boundary condition : $\varphi_{5(i)} = 0, \ \forall i$.

- Answer : $\varphi^* = \varphi_1(i), \forall i$.

Using the answer φ^*, we can identify the optimal route.

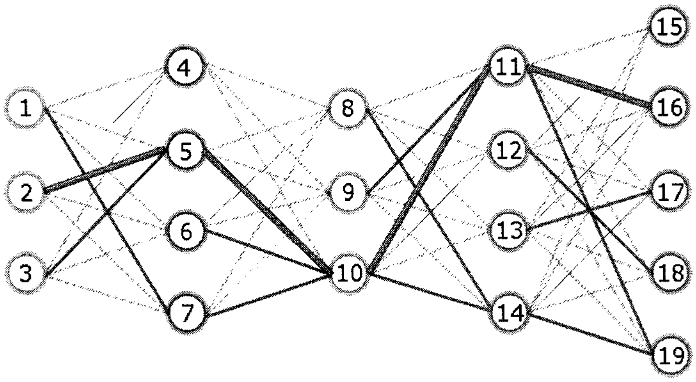
5. Numerical Illustrations

Here, we illustrate the proposed model by an example. We assume that a five layer supply chain and four attributes are considered to evaluate the interactions between elements of each pair of layers. The weights for the stated attributes are assumed to be $\beta_1 = 0.2$, $\beta_2 = 0.3$, $\beta_3 = 0.1$, and $\beta_4 = 0.4$, respectively. The interactions and corresponding scores, normalized values, and weighted normalized values are shown in <Table 6>.

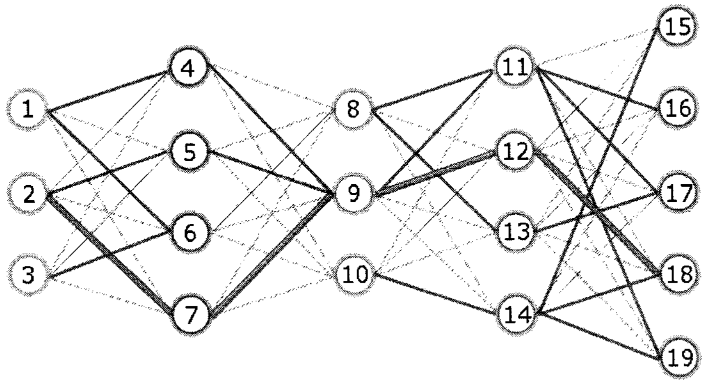
Using the information in <Table 6>, the element-to-element matrix is configured. Then, using the element-to-element matrix, we compute the threshold values corresponding to the interactions. The results of threshold computations are shown in <Table 7>.

Considering a confidence level of 95% and using standard normal distribution tables, we obtain Z95% = 1.96. Thus, any α value lower than 1.96 is considered to be inappropriate and hence omitted from the process. After eliminating the inappropriate scores and applying the dynamic program, we identify the optimal route in the proposed multi layer supply chain. In <Figure 4>, the blue lines are the remaining interactions after the threshold analysis and the bold red lines show the optimal route obtained using the dynamic program. The optimal route is 2→5→10→11→16 and the corresponding optimal value is: 2.867 + 1.969 + 2.755 + 2.751 = 10.342.

We performed the same process for a different period. After the corresponding computations, another route was obtained as an optimal route. The difference between the optimal routes corresponding to the two periods is due to variety in requirements and interests of the elements of the layers in different time periods. The configuration of optimal route in



<Figure 4> The obtained optimal route



<Figure 5> The configuration of optimal route in the second period

〈Table 6〉 DATA Entries for the proposed example

	A_1	A_2	A_3	A_4	N_1	N_2	N_3	N_4	$\beta_1 \times N_1$	$\beta_2 \times N_2$	$\beta_3 \times N_3$	$\beta_4 \times N_4$
$a_{1,4}$	5	3	2	7	0.1326	0.0828	0.0527	0.1627	0.0265	0.0248	0.0052	0.0651
$a_{1,5}$	1	2	7	9	0.0265	0.0552	0.1846	0.2093	0.0053	0.0165	0.0184	0.0837
$a_{1,6}$	4	3	5	8	0.1061	0.0828	0.1318	0.1860	0.0212	0.0248	0.0131	0.0744
$a_{1,7}$	1	2	5	7	0.0265	0.0552	0.1318	0.1627	0.0053	0.0165	0.0131	0.0651
$a_{2,4}$	6	4	3	7	0.1592	0.1105	0.0791	0.1627	0.0318	0.0331	0.0079	0.0651
$a_{2,5}$	2	5	4	1	0.0530	0.1381	0.1055	0.0232	0.0106	0.0414	0.0105	0.0093
$a_{2,6}$	3	4	5	6	0.0796	0.1105	0.1318	0.1395	0.0159	0.0331	0.0131	0.0558
$a_{2,7}$	7	8	9	1	0.1857	0.2210	0.2374	0.0232	0.0371	0.0663	0.0237	0.0093
$a_{3,4}$	3	5	2	7	0.0796	0.1381	0.0527	0.1627	0.0159	0.0414	0.0052	0.0651
$a_{3,5}$	6	8	2	8	0.1592	0.2210	0.0527	0.1860	0.0318	0.0663	0.0052	0.0744
$a_{3,6}$	5	4	1	3	0.1326	0.1105	0.0263	0.0697	0.0265	0.0331	0.0026	0.0279
$a_{3,7}$	6	2	4	5	0.1592	0.0552	0.1055	0.1162	0.0318	0.0165	0.0105	0.0465
$a_{4,8}$	7	9	5	1	0.1857	0.2486	0.1318	0.0232	0.0371	0.0745	0.0131	0.0093
$a_{4,9}$	4	1	8	3	0.1061	0.0276	0.2110	0.0697	0.0212	0.0082	0.0211	0.0279
$a_{4,10}$	9	1	2	4	0.2388	0.0276	0.0527	0.0930	0.0477	0.0082	0.0052	0.0372
$a_{5,8}$	9	2	1	5	0.2388	0.0552	0.0263	0.1162	0.0477	0.0165	0.0026	0.0465
$a_{5,9}$	9	1	7	5	0.2388	0.0276	0.1846	0.1162	0.0477	0.0082	0.0184	0.0465
$a_{5,10}$	4	9	1	6	0.1061	0.2486	0.0263	0.1395	0.0212	0.0745	0.0026	0.0558
$a_{6,8}$	2	1	3	9	0.0530	0.0276	0.0791	0.2093	0.0106	0.0082	0.0079	0.0837
$a_{6,9}$	6	7	1	3	0.1592	0.1934	0.0263	0.0697	0.0318	0.0580	0.0026	0.0279
$a_{6,10}$	8	9	2	4	0.2122	0.2486	0.0527	0.0930	0.0424	0.0745	0.0052	0.0372
$a_{7,8}$	1	6	2	8	0.0265	0.1657	0.0527	0.1860	0.0053	0.0497	0.0052	0.0744
$a_{7,9}$	9	1	7	6	0.2388	0.0276	0.1846	0.1395	0.0477	0.0082	0.0184	0.0558
$a_{7,10}$	4	1	9	6	0.1061	0.0276	0.2374	0.1395	0.0212	0.0082	0.0237	0.0558
$a_{8,11}$	2	8	6	4	0.0530	0.2210	0.1582	0.0930	0.0106	0.0663	0.0158	0.0372
$a_{8,12}$	1	3	5	7	0.0265	0.0828	0.1318	0.1627	0.0053	0.0248	0.0131	0.0651
$a_{8,13}$	9	5	1	3	0.2388	0.1381	0.0263	0.0697	0.0477	0.0414	0.0026	0.0279
$a_{8,14}$	2	4	6	1	0.0530	0.1105	0.1582	0.0232	0.0106	0.0331	0.0158	0.0093
$a_{9,11}$	6	5	9	8	0.1592	0.1381	0.2374	0.1860	0.0318	0.0414	0.0237	0.0744
$a_{9,12}$	1	2	4	6	0.0265	0.0552	0.1055	0.1395	0.0053	0.0165	0.0105	0.0558
$a_{9,13}$	3	5	4	1	0.0796	0.1381	0.1055	0.0232	0.0159	0.0414	0.0105	0.0093
$a_{9,14}$	2	1	8	9	0.0530	0.0276	0.2110	0.2093	0.0106	0.0082	0.0211	0.0837
$a_{10,11}$	8	7	9	9	0.2122	0.1934	0.2374	0.2093	0.0424	0.0580	0.0237	0.0837
$a_{10,12}$	1	7	6	2	0.0265	0.1934	0.1582	0.0465	0.0053	0.0580	0.0158	0.0186
$a_{10,13}$	3	5	4	1	0.0796	0.1381	0.1055	0.0232	0.0159	0.0414	0.0105	0.0093
$a_{10,14}$	1	1	1	1	0.0265	0.0276	0.0263	0.0232	0.0053	0.0082	0.0026	0.0093
$a_{11,15}$	5	2	9	8	0.1326	0.0552	0.2374	0.1860	0.0265	0.0165	0.0237	0.0744
$a_{11,16}$	1	6	1	1	0.0265	0.1657	0.0263	0.0232	0.0053	0.0497	0.0026	0.0093
$a_{11,17}$	1	2	8	8	0.0265	0.0552	0.2110	0.1860	0.0053	0.0165	0.0211	0.0744
$a_{11,18}$	3	2	1	5	0.0796	0.0552	0.0263	0.1162	0.0159	0.0165	0.0026	0.0465
$a_{11,19}$	4	3	7	9	0.1061	0.0828	0.1846	0.2093	0.0212	0.0248	0.0184	0.0837
$a_{12,15}$	2	4	1	7	0.0530	0.1105	0.0263	0.1627	0.0106	0.0331	0.0026	0.0651
$a_{12,16}$	1	6	5	3	0.0265	0.1657	0.1318	0.0697	0.0053	0.0497	0.0131	0.0279
$a_{12,17}$	2	3	2	8	0.0530	0.0828	0.0527	0.1860	0.0106	0.0248	0.0052	0.0744
$a_{12,18}$	9	4	5	6	0.2388	0.1105	0.1318	0.1395	0.0477	0.0331	0.0131	0.0558
$a_{12,19}$	1	3	2	7	0.0265	0.0828	0.0527	0.1627	0.0053	0.0248	0.0052	0.0651
$a_{13,15}$	2	5	6	1	0.0530	0.1381	0.1582	0.0232	0.0106	0.0414	0.0158	0.0093
$a_{13,16}$	3	4	2	8	0.0796	0.1105	0.0527	0.1860	0.0159	0.0331	0.0052	0.0744
$a_{13,17}$	9	5	5	5	0.2388	0.1381	0.1318	0.1162	0.0477	0.0414	0.0131	0.0465
$a_{13,18}$	3	3	3	4	0.0796	0.0828	0.0791	0.0930	0.0159	0.0248	0.0079	0.0372
$a_{13,19}$	2	5	6	1	0.0530	0.1381	0.1582	0.0232	0.0106	0.0414	0.0158	0.0093
$a_{14,15}$	8	9	2	3	0.2122	0.2486	0.0527	0.0697	0.0424	0.0745	0.0052	0.0279
$a_{14,16}$	7	4	5	1	0.1857	0.1105	0.1318	0.0232	0.0371	0.0331	0.0131	0.0093
$a_{14,17}$	1	3	5	5	0.0265	0.0828	0.1318	0.1162	0.0053	0.0248	0.0131	0.0465
$a_{14,18}$	2	5	3	3	0.0530	0.1381	0.0791	0.0697	0.0106	0.0414	0.0079	0.0279
$a_{14,19}$	8	7	7	9	0.2122	0.1934	0.1846	0.2093	0.0424	0.0580	0.0184	0.0837

〈Table 7〉 The results of threshold computations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0	0	0	0.262	0.584	1.946	2.793	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	1.419	2.867	0.126	1.321	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0.126	2.745	1.835	1.037	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	1.870	1.549	0.320	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	1.285	0.683	1.969	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	1.311	0.651	1.963	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	1.264	0.709	1.974	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	1.734	0.127	0.971	2.833	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	2.652	1.267	1.787	0.403	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	2.755	0.113	0.648	1.993	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.879	2.751	0.392	1.837	2.316
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.331	1.955	0.053	3.721	1.488
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.781	1.698	3.057	1.192	1.781
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.124	1.404	1.532	1.620	3.433
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

the new period is shown in <Figure 5>.

The optimal route is 2→7→9→12→18 with the corresponding optimal value of $2.679+1.998+2.662+3.695=11.034$.

All computations and configurations of the proposed SCM were carried out using an intelligent agent encoded in JAVA programming language.

6. Conclusions

We proposed an information system to integrate the elements of a multi layer agent based SCM. We showed how to design the information systems for the layers and trace the information flows. In each layer, the intelligent agents collect information and produce a report which includes the flow of multi attribute decision makings. A new method was presented for the information flow of interactions using a dynamic programming approach. The advantages of the system are real time decision making and optimal route selection.

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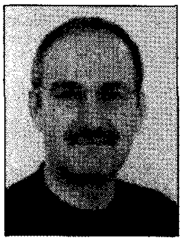

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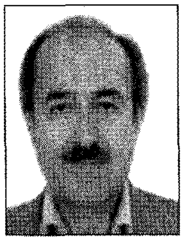

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