Research on the construction of supply chain network based on fixed spread risk

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Abstract: Supply chain is an integrated network where suppliers, sellers and customers are highly interconnected through business activities. The basic character of supply chain is complexity, dynamic and growth. In this paper, based on the complex network theory, we build a supply chain network model based on gradual risk. The dynamic growth mechanism of the supply chain network is based on the local world evolving model. The new node adds the local world entering with a certain probability. Combined with supply chain, the node, the edge and the weighted and the network are being redefined. The process of how new added node assign risk to old nodes is also introduced

Keywords: Supply Chain, Complex Networks, Risk Model, Generation Process

1. Introduction

Supply chain is a value network which is used to describe activity of each entity and their mutual relations. Or to be more precise, it described the process of businesses' flows, such as material, information and financial, from upstream enterprise to downstream enterprise [1-4]. Due to today's uncertain and turbulent changeable environment, supply chain enterprises today face various factors of uncertainties, which causing the enterprises can not work well. How to treat the influence of supply chain vulnerability on supply chain enterprises and how to take appropriate measures and subsequently control them has become an issue of significance for many companies [5].

Complex network is a useful tool to analyze the impact of risk spread on supply chain [6-10]. There has been increased attention focused on supply chain risk from various directions. Fabrizio Natalea et al [11] build a movement network to simulate epidemic spread in supply chain. Monique A. van der Gaaga Fred Vosa et al. [12] design a detailed stochastic state transition model and analyze its characteristics. Kathrin Buttnera et al [13] present a static poultry trade supply chain network to analyze its statistic characteristics. In this paper, we mainly study on construction of supply chain risk network based on complex network theory.

The rest of this paper is organized as follows: In the next section, we outline the risk spread model and put forward the definition of node, edge and weight. In section 3, we describe the process of supply chain risk network modeling, including the Selection of Local World, the process of the joining a new node and distributing risk value. In Section 4, we draw some concluding remarks.

2. Risk Network Model

The supply chain's contact structure may be visualized in terms of a network or graph. Each of the nodes in the network represents an enterprise which consists of supply, seller and customer. An edge is placed between any pair of enterprise who establishes relationship with each other. The resulting network topology is summarized by the symmetric adjacency matrix A who elements $a_{ij} = 0$ if there is the absence of such a contact, while $a_{ij} = 1$ or $a_{ij} = -1$ if there is a contact between the node enterprise i and j, which from upstream entity to downstream entity or contrary direction.

2.1. Definition of Node

The supply chain risk node is defined as $vi = (ID, Category, Level, Risk)$, where ID standards for the number of nodes in the supply chain, which is used to distinguish the different members of the enterprise; $Category$ is a classification identifier of the node; The $level$ of node shows the business order in supply chain;

risk represents all kinds of risk that exists in supply chain risk network.

The node enterprises in supply chain network are divided into suppliers, sellers and customers in accordance with their business in the supply chain. The functions of the supplier to provide raw materials and finished products; the functions of the sellers is the procurement of goods and finished products to its upstream suppliers or vendors sold its downstream enterprises; the functions of the customer is the procurement of goods to the seller.

2.2. Definition of Edge

The edge expresses business relationship between business entities v_i, v_j in the supply chain. There will be an edge between node v_i, v_j if the business between business entities v_i, v_j which express adjacent and downstream enterprises is related, or there is no. The edge denoted by $e = (v_i, v_j)$, e is called the associated edge of nodes v_i, v_j. Call v_i, v_j as the end of e.

2.3. Definition of Weight

In the supply chain, the weight w_{ij} expresses logistics quantity between node v_i and node v_j. The weight can be distinguished dissimilarity weight and similarity weight. And the dissimilarity weight is similar to the traditional distance, the greater the value, the bigger the distance and the more distant the relationship between two points. Similarity weight is conversely, the greater weight said the more intimate relationship, the smaller the distance between two points. So this paper uses the dissimilarity weight. And the direction of edge in the supply chain expresses the order of business between the associated enterprises; the starting node level must be less than the end nodes. That is, the level of the business entities v_i should be less than the level of business entities v_j. It is to ensure that the edge direction and supply chain logistics volume in the same direction. So the w_{ij} expresses the weight from node v_i to node v_j. It is the incoming edge weight for v_i, but outgoing edge weight for v_j, and $w_{ij} = w_{ji}$.

2.4. The Supply Chain Risk

The network conceptual framework has been very useful for the description and analysis of the risk of transmission. Now, we will present the basic definitions of the components of risk network:

i) Risk source: the source of risk transmission is defined as risk source. The origin of risk by classification can be divided into external risks and internal risk. The risks caused by market fluctuations or government policy is often referred to as external risks; internal risks is any loss events that caused by internal operations.

ii) Risk nodes: in supply chain risk network, every enterprise can be called as risk nodes. Classify them by conduction target, risk nodes can be divided into risk object and risk subject. The risk nodes that transmit risk are referred to as risk object. Relatively, the risk nodes that infected risk are referred to as risk object. With the difference of risk source, any nodes can become risk object, as long as it is an originator. The same condition applies to risk subject.

iii) Risk carriers: in the process of conduction, risk at its essence is an intangible item that transmitted associated risk nodes through "the medium" or "the bridge", and these "media" or "bridges" are the risk conduction carriers. The risk conduction carrier has five characteristics: objectivity, multiplicity, load bearing, conductivity and orderliness. For different properties of risk carriers and risk source attribute, risks have had transmitted dependent on different medium.

iv) Transmission pathways: it can be defined as the logical distance of risk transmitted from one node to another. For different conduction pathways, the modes of risk conduction are different. In this network, transmission pathways started from suppliers, through sellers and finally reaching customers. Risk will attach to all kinds of carriers

v) Risk threshold: In the supply chain network, each enterprise itself has a certain tolerance for risk. The threshold is a value that determines whether the node enterprises can normally transmit material/product, information and finance. When this limit is reached, risk will be transmitted form upstream business entity to downstream.

3. Generation Process

3.1. The Selection of Local World

In the directed supply chain network, the new added node will select cooperation partners and then establish relation with them, so its local world is all the associated nodes.

According to the categories and level of nodes, there are three ways to select:

a) When the new added node is supplier, it will establish business relation with other suppliers or sellers, so all the suppliers and sellers are selected as its local world.

b) When the new added node is seller, it will establish business relation with suppliers; customers or other sellers, so all nodes of the network are selected as its local world.

c) When the new added node is customer, it will establish business relation with sellers, so all the sellers are selected as its local world.

3.2. Connection Mechanism

At each step of the evolution, generate a number e of edges and connect them together by adding new node, or, to put it another way, a new added node can establish business relation with k nodes by immanent probability. In this paper, one must take into consider that the node's risk value may affect its probability proportional of node connection. The

connection probability proportional $p_{connection}(k)$ is defined by

$$p_{connection}(k) = \frac{\prod_{l \in A}^{m} r(l) - r(k)}{(m-1) * \prod_{l \in A}^{m} r(l)} \quad (1)$$

Here, m is the total number of risk nodes, $r(k)$ is the risk value of new node k, $r(l)$ is the risk value of its associated node. A is the ultimate supply chain network.

According to different categories and level of nodes, we have the following algorithm:

(i) As a new supplier, it connects to existed node within its local world. In supply chain, each new node will bring e_1 edges which include e_{1in} incoming edges and e_{1out} outgoing edges. Goods or raw materials are always flowing from lower level node and finally arriving the higher one. Because the lowest-level suppliers have no supply channel, so e_{1in} can be 0, but e_{1out} not.

(ii) As a new seller, it connects to existed node within its local world. In supply chain, each new node will bring e_2 edges which include e_{2in} incoming edges and e_{2out} outgoing edges. Goods or raw materials are always flowing from lower level node and finally arriving the higher one. Because each seller must has supply channel and sale channel, so e_{2in} and e_{2out} can not be 0.

(iii) As a new customer, it connects to existed node within its local world. In supply chain, each new node will bring e_3 edges which include e_{3in} incoming edges and e_{3out} outgoing edges. Goods or raw materials are always flowing from lower level node and finally arriving the higher one. Because each seller must have supply channel and sale channel, so e_{3out} can be 0, but e_{3in} not.

3.3. Risk Allocation Process

In this paper, we assume that the risk value of the associated nodes in the supply chain network model is distributed according to a given risk value $r(k)$. However, each assigned risk value is random, so we must calculate the probability proportional $p(i)$. The distribution probability proportional $p_{distribution}(i)$ is defined by:

$$p_{distribution}(i) = \frac{2 \arctan \left| \frac{1}{r(k) - 40} \right|}{\pi} * \frac{\prod_{l \in A}^{n} r(l) - r(i)}{(n-1) * \prod_{l \in A}^{n} r(l)} \quad (2)$$

Here, $r(l)$ is all risk value of its associated risk nodes, $r(i)$ is the risk value of its associated risk nodes i, n is the total number of its associated risk nodes.

Then, we immediately have the actual risk value $r'(i)$

$$r'(i) = r(i) + r(i) * p_{distribution}(i)$$

Here, the risk value is cumulated process. We must calculate all risk value of added node which associated with node i. The final cumulated value is the actually risk value of nodes i.

3.4. Molding Process

The supply chain network model based on risk connection is generated by the following algorithm:
1) Start with a small number m0 of nodes and confirm the risk of node, the edges, direction and its risk spread probability.
2) A new coming node enters into the supply chain network, select its local world from the existing network.
3) The new coming nodes connected with existed nodes by probability $p_{connection}(k)$.
4) The risk value of associated nodes increase by probability $p_{distribution}(i)$
5) Modify the risk of associated node by using formula (1) and (2).
6) Repeat 2), 3), 4), 5) until the number of nodes in the network reaches to N.

4. Conclusions

Networks are not only relevant for many current issues but have found application in a variety of supply chain systems. In this paper, we present a weighted supply chain complex network model based on risk. The nodes of model are classified into three types, including supplier, seller and customer. For different categories and level of node, its local world and connection mechanism are different. Furthermore, the new added node is possible to affect its associated nodes.

Acknowledgments

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