Research on Risk Nodes of Live Broadcast E-Commerce Supply Chain Based on Complex Network

Jiaxin Liu [1], Jinhong Wang [2*]

[1] Liaoning Technical University, Liaoning, Huludao, 125000, China
[2] Liaoning Technical University, Liaoning, Fuxin, 123000, China
*626257905@qq.com

Abstract. To prevent and reduce the occurrence and proliferation of live e-commerce supply chain risk events. Firstly, based on complex network theory, we construct a live e-commerce supply chain risk network model and analyze the overall network characteristics of the live e-commerce supply chain risk node network; secondly, we calculate the network risk node degree centrality and betweenness centrality, and carry out classification research on the nodes; finally, we calculate the network edge betweenness and find out the key connecting edges and point out the chain-breaking measures to avoid the further propagation of risks.

Keywords: Live e-commerce, supply chain risk nodes, risk propagation, complex network theory.

1 INTRODUCTION

As a new mode of commodity sales, live e-commerce provides consumers with timely, rich and interactive commodity displays, and has become a powerful driver to promote the development of online economy. However, as live e-commerce involves brands, anchors, MCN organizations and other stakeholders, each stakeholder pays more attention to its own interests and lacks attention to the overall interests of the supply chain. In addition, live e-commerce is susceptible to market changes, marketing environment and other aspects of the impact of its logistics, information flow, capital flow and other aspects of poor circulation, resulting in a decline in the overall performance of the supply chain. Therefore, accurately identifying the risk nodes of the live e-commerce supply chain and blocking the further propagation of risks are of great significance for maintaining the security and stability of the live e-commerce supply chain.

Regarding supply chain risk, domestic and foreign scholars mainly carry out risk assessment and control by constructing a risk framework. Christopher S. Tang [1] controls supply chain risk by constructing a risk management framework; Cheng [2]establishes a multi-dimensional risk identification framework to identify the key risk sources of the engineering supply chain for identification; Zhao [3] assesses sup-

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ply chain risk by constructing a systematic supply chain security risk multi-level indicator system.

Complex networks are an effective method to study complex systems, which are now widely used in the fields of medicine [4][5], transportation [6], power systems [7], and social sciences [8][9]. The occurrence and development of supply chain risk presents a dynamic chain reaction, which is consistent with the basic characteristics of complex networks. Liu [10]and Huang [11]use complex network theory to construct a supply chain risk network model, analyze the transmission effect between risks, and explore the key risk nodes.

In conclusion, the research on supply chain risk has achieved a lot of results, but the research on the correlation relationship between risk nodes is still in the initial stage. Therefore, this paper applies complex network theory to the identification and analysis of risk nodes in live e-commerce supply chain. Using complex network theory to construct a live e-commerce supply chain risk network model, identify the key risk nodes of the supply chain, cut off the connecting edges of the risk nodes, effectively control the occurrence and spread of supply chain risk events, and ensure the stable operation of the supply chain.

2 LIVE E-COMMERCE SUPPLY CHAIN RISK NETWORK CONSTRUCTION

2.1 Risk Factor Analysis

The supply chain of live e-commerce gathers many subjects such as brands, multichannel network, anchors, social media platforms, logistics service providers and so on. This paper collects 25 risk factors of live e-commerce supply chain in terms of market risk, operation risk, cooperation risk, external environment risk, public opinion risk, logistics risk, etc. by combing the relationship among subjects and combining the opinions of key players in the industry and other professionals, as shown in Table 1.

Table 1. Risk factors in the supply chain of live streaming e-commerce.

Causal classification	Disaster-causing factors
Market Risk R1	R11Changing supply and demand, R12 High return rate, R13 Imperfect monitoring mechanisms
Operational Risk R2	R21Broken capital chain, R22 Blocked marketing channels, R23 Insufficient personnel professionalism
Collaboration Risk R3	R31 Supply chain imbalance, R32 Information asymmetry, R33 Uneven distribution of benefits, R34 Adverse selection of enterprises, R35 Lack of trust among partners
Environmental Risk R4	R41 Economic environment changes, R42 Natural disaster, R43 Major national activities
Public opinion Risk R5	R51Anchor's inappropriate words and behavior, R52Product quality issues, R53 Create fake traffic, R54Uncivilized sales, R55Misleading prices
Logistics Risk R6	R61Incomplete facilities, R62Logistics delays, R63Loss of goods, R64untimely shipment, R65Poor logistics information, R66Increased transportation costs

2.2 Modeling Risk Networks

Due to the correlation between risk factors, the generation of a risk event may cause a series of risk events. Risk factors as a complex network of "nodes", the correlation between the risk events as a complex network of "connecting edges", to build a risk event network model. An example of a risk event chain is as follows, R21→R62→R12, where a break in the financial chain leads to a delay in logistics, which in turn leads to a high rate of merchandise returns. By integrating all risk event chains with each other, the key risk node network of live e-commerce supply chain with 25 nodes and 73 connecting edges is obtained by using pajek software, as shown in Figure 1.

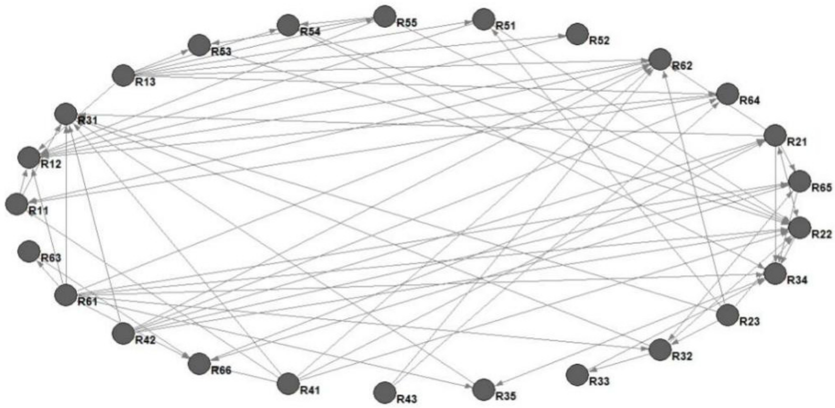

Fig. 1. Live e-commerce supply chain risk network

3 CHARACTERIZATION OF SUPPLY CHAIN RISK NETWORKS IN LIVE E-COMMERCE

3.1 Small-World Characterization Tests

Small-world networks have larger clustering coefficients and smaller average path lengths. Using pajek software, the clustering coefficient of the risk network is calculated to be 0.192 and the average path length to be 2.227. Meanwhile, 10 random networks with 27 nodes and 73 connected edges are constructed, and the clustering coefficient and the average path length of these 10 random networks are calculated, as shown in Table 2.

Table 2. Clustering coefficient and average path length of 10 random networks.

	1	2	3	4	5	6	7	8	9	10	average
Clustering coefficient	0.147	0.115	0.107	0.106	0.098	0.091	0.094	0.101	0.112	0.111	0.108
Average path length	2.889	2.809	2.700	2.677	2.794	2.769	2.648	2.785	2.825	2.775	2.767

According to Table 2, the supply chain risk network has larger clustering coefficients and smaller average path lengths compared to random networks, so the live e-commerce supply chain risk network conforms to the general characteristics of the small world network [12]. Therefore, the nodes of this network are more closely connected, and the generation of a certain risk event is more likely to cause the generation of other risk events, which should be prevented and controlled in a timely manner to prevent the supply chain risk network cascade effect.

3.2 Risk Network Centrality Analysis

Degree centrality. The degree centrality of a node is the most direct metric for portraying the centrality of a node in network analysis, and the larger the node degree of a node means that the node's degree centrality is higher, and the node is more important in the network. Since the live e-commerce supply chain risk network constructed is a directed network, the node degree is further divided into out-degree and in-degree, and the node degree of the network is calculated using Pajek software to obtain the point degree, output-degree and input-degree of each risk node, as shown in Table 3.

Table 3. The value of the risk nodes.

Node	output	input	all	Node	output	input	all	Node	output	input	all
R11	2	3	5	R34	1	7	8	R55	4	1	5
R12	0	8	8	R35	2	2	4	R61	10	0	10
R13	8	0	8	R41	6	0	6	R62	2	7	9
R21	5	4	9	R42	6	0	6	R63	1	1	2
R22	2	10	12	R43	2	0	2	R64	2	3	5
R23	5	0	5	R51	2	2	4	R65	3	4	7
R31	0	8	8	R52	1	1	2	R66	1	4	5
R32	4	3	7	R53	1	2	3				
R33	1	1	2	R54	2	2	4				

Betweenness Centrality. Node betweenness centrality is the importance of a node portrayed in terms of the number of shortest paths through the node, the more the number of shortest paths through the node, the more pivotal the node is. The node betweenness centrality is calculated and ranked with the help of pajek software and the results are shown in Table 4.

Table 4. Betweenness centrality of risk nodes.

Node	Betweenness centrality	Node	Betweenness centrality	Node	Betweenness centrality
R21	0.130 737	R64	0.006 341	R13	0.000 000
R22	0.096 618	R35	0.004 529	R52	0.000 000
R65	0.060 386	R51	0.003 623	R23	0.000 000
R62	0.044 384	R53	0.002 717	R43	0.000 000
R32	0.032 609	R55	0.002 717	R41	0.000 000
R34	0.029 891	R33	0.001 208	R42	0.000 000
R66	0.028 080	R12	0.000 000	R61	0.000 000
R11	0.008 152	R31	0.000 000	R63	0.000 000
R54	0.008 152				

Node classification. Combining the centrality analyses in Tables 3 and 4, the nodes can be classified into the following four categories. Nodes with smaller input-degree and larger output-degree are causal nodes of the risk network; nodes with larger degree and betweenness centrality are intermediate nodes of the risk network; nodes with larger input-degree but smaller output-degree and betweenness centrality are resultant nodes of the risk network; and nodes with smaller point and betweenness centrality are edge nodes of the risk network, as shown in Table 5.

Table 5. Classification of risk nodes.

Classification	Risk nodes
Causal nodes	R13Imperfect monitoring mechanisms,R23Insufficient personnel professionalism,R41 Economic environment changes,R42 Natural disaster, R43Major national activities,R55Misleading prices,R61Incomplete facilities
Intermediate nodes	R11Changing supply and demand,R21Broken capital chain, R22Blocked marketing channels,R32 Information asymmetry, R34 Adverse selection of enterprises,R54Uncivilized sales, R62Logistics delays,R65Poor logistics information
Result nodes	R12High return rate,R31Supply chain imbalance, R66Increased transportation costs
Edge nodes	R33Uneven distribution of benefits,R35Lack of trust among partners, R51Anchor's inappropriate words and behavior,R52Product quality issues, R53Create fake traffic,R63Loss of goods,R64untimely shipment

Causal nodes are the starting point for the occurrence of risks and should be controlled in a focused manner; the intermediate nodes are the bridge for further spreading of risks, and it is necessary to carry out real-time monitoring of risks to achieve timely cut-off; the result node is the consequence of the risk event, which can be avoided by focusing on the causal nodes and the intermediate nodes; edge nodes are less central and less risky, but still try to avoid the emergence of related risks.

4 RISK NETWORK BROKEN CHAIN ANALYSIS

The degree of interaction between risk nodes in the risk network can be measured by the edge betweenness. MATLAB is used to calculate the edge betweenness of each connecting edge in the live e-commerce supply chain risk network, and the first five connecting edges with larger edge betweenness are taken, as shown in Table 6.

Table 6. Edge betweenness of each connecting edge(top five).

connecting edge	R22-R21	R21-R65	R21-R62	R66-R21	R65-R32
edge betweenness	53.00	37.00	28.00	26.50	26.00

The larger the edge betweennes, the higher the degree of influence between the two risk nodes, and the greater the intensity of risk propagation, so the focus should be on the above connecting edges to take chain-breaking measures to avoid further propagation of risk, the specific chain-breaking measures, as shown in Table 7.

Table 7. Connected edges with large edge betweenness and chain breaking measures.

connecting edge	chain breaking measures
Blocked marketing channels →Broken capital chain	Provide quality services, develop word-of-mouth marketing, and broaden marketing channels; pay attention to cash flow planning and changes in the economic environment.
Broken capital chain →Poor logistics information	Pay attention to cash flow planning and changes in the economic environment; strengthening communication, distribution and other infrastructure construction, and upgrading the level of logistics informatization.
Broken capital chain →Logistics delays	Pay attention to cash flow planning and changes in the economic environment; improvement of logistics facilities and real-time monitoring of logistics and transportation conditions.
Increased transportation costs →Broken capital chain	Adopting a full supply chain management model that emphasizes "synergies" between sectors; pay attention to cash flow planning and changes in the economic environment.
Poor logistics information →Information asymmetry	Strengthening communication, distribution and other infrastructure construction, and upgrading the level of logistics informatization; establish an information-sharing platform and strengthen communication and coordination.

5 CONCLUSION

Using complex network theory to construct the live e-commerce supply chain risk node network, analyze the overall characteristics of the network, and find that the live e-commerce supply chain risk node network has the characteristics of small world network; Classify risk nodes by analyzing node degree centrality and betweenness centrality; Calculate network edge betweenness, identify key connecting edges, and propose chain-breaking measures to block the further propagation of risk and reduce the loss and impact of a risk on the supply chain as a whole.

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