sustainability

Article

Scenario-Based Supply Chain Resilience Analysis of Bearings

Feng Lyu [1,*], Fen Liu [1], Shuping Zhang [1] and Zhiwen Zhang [1,2]

[1] School of Mechatronics Engineering, Henan University of Science and Technology, Luoyang 471003, China; 220320010149@stu.haust.edu.cn (F.L.); 220320010148@stu.haust.edu.cn (S.Z.); lyzhangzhiwen@126.com (Z.Z.)
[2] Longmen Laboratory, Luoyang 471003, China
* Correspondence: lvfeng1980@haust.edu.cn

Abstract: Bearings, as an indispensable part of modern industry, and the related supply chain resilience in regard to maintaining the overall operational efficiency and competitiveness of the manufacturing industry, are highly significant. Integrating the triangular fuzzy number (TRFN), cross-influence analysis (CIA), and the adversarial interpretive structure model (AISM), this paper proposes a TCIA-AISM scenario model to analyze the resilience of the bearing supply chain. A hierarchical structure diagram is formed to clarify the transmission path of events that affect bearing supply chain resilience, identify the root cause and direct events that affect the results, and realize the visual analysis of such events. The probability of the outcome is predicted and the simulation of the scenario development trajectory provides a scientific basis for decision-makers to formulate reasonable emergency strategies. The validity of the method is verified by using an interruption event involving the G-enterprise case study as an example.

Keywords: bearing supply chain; resilience; TCIA-AISM; scenario deduction

1. Introduction

Bearings are an indispensable part of mechanical equipment [1]; they support the rotating parts, transfer load and rotary motion of such equipment, and the quality, performance, and reliability of such components directly determines the operating efficiency and service life of mechanical equipment [2]. Bearings have a wide application potential across modern industry; whether it is in automotive, aerospace, wind power, or machine tool fields, bearings play a vital role, and the technical level of bearings largely represents the overall strength and scientific and technological development level of a country's equipment manufacturing industry [3]. The complexity of the bearing supply chain is reflected in its long supply chain, its multiple links, and its high level of dependence on raw materials. In the increasingly complex international environment, the risk of disruption to the bearing supply chain has intensified. Supply chain security is not only related to the steady operation of enterprises and the overall security of the industry, but also has a profound impact on the economic security and strategic interests of a country. Supply chain resilience refers to the ability of a supply chain to adapt, recover, and even grow in the face of external shocks and uncertainties [4]. Resilience is the key to ensuring the health and stability of a supply chain, allowing it to quickly adjust and recover in the event of a challenge. Supply chain resilience is also an important driver of supply chain sustainability, by reducing the loss and waste of resources due to disruption, thereby contributing to the dual objectives of economic efficiency and environmental protection [5].

In order to maintain the security and stability of the supply chain, scholars have conducted a large number of studies on supply chain resilience. In 2004, supply chain resilience was first defined by Christopher and Peck. With the deepening of such research, scholars have focused on the influencing factors, measurement and evaluation, optimization, and other aspects of supply chain resilience. Ali et al. [6] classified supply chain

Citation: Lyu, F.; Liu, F.; Zhang, S.; Zhang, Z. Scenario-Based Supply Chain Resilience Analysis of Bearings. *Sustainability* **2024**, *16*, 9069. https://doi.org/10.3390/su16209069

Academic Editors: Katarzyna Grondys, Oksana Seroka-Stolka and Marta Kadłubek

Received: 11 September 2024
Revised: 2 October 2024
Accepted: 9 October 2024
Published: 19 October 2024

resilience into prediction, monitoring, response, and learning capabilities, and systematically summarized the factors that affect supply chain resilience. Some scholars have also studied the impact of agility and robustness [7], flexibility and adaptability [8], connectivity and visibility [9], supply chain relationships and collaboration [10], and risk management culture [11] on supply chain resilience in terms of each dimensions' own capabilities. When scholars measure and evaluate supply chains, they mainly carry out measurements directly using quantitative indicators [8], they quantify the qualitative evaluation [12–15], and they quantify the resilience from the perspective of complex networks [16]. Research on supply chain optimization is mostly carried out through mathematical modeling, such as multi-objective linear programming, stochastic programming, and goal programming methods, which are mainly used to study the optimal supply chain structure in the context of target resilience [17–19].

The following gaps and shortcomings have been found in previous studies: (1) The current resilience research field does not cover the bearing supply chain. (2) There is a lack of systematic analysis on the coupling relationship between events, as well as cascading effects. (3) The probability of an event occurring in regard to the CIA method is mainly determined by two methods, namely, through historical data collection, which is highly precise but difficult to obtain or may be unquantifiable, and the Delphi method, which is highly effective in assessing the situation, but the subjectivity and uncertainty related to expert assessments are too strong when dealing with a complex system. (4) ISM constructs a system's hierarchy based primarily on outcome-first hierarchy extraction rules, and this single perspective cannot fully reveal the complex relationships and dynamic changes among the internal elements of a system.

Therefore, this paper proposes an integrated approach based on the TRFN, CIA, and AISM to analyze the supply chain resilience of bearings, with full consideration of the interaction mechanism between the influencing factors. The TRFN was used to convert the subjective and uncertain qualitative evaluations of experts into quantitative values through standardized logic operations, eliminating subjective differences. CIA was introduced to generate scenarios and the AISM was used to draw hierarchical structure diagrams to realize the visual analysis of key events and clarify the linkage effect in terms of the conduction path of events. Taking G-enterprise disruption events as an example, a representative scenario is constructed to predict the impact of a particular event on the resulting outcome.

The rest of this paper is organized as follows: Section 2 describes the approach to constructing the scenario model, as well as the steps in the process. Section 3 describes the case study conducted to study a specific application of the TCIA-AISM methodology and to prove the feasibility of the presented approach by means of a G-enterprise case study. Section 4 presents the conclusions.

2. Materials and Methods

CIA is a complex analytical method, suitable for assessing the impacts of interacting relationships on specific outcomes or goals [20]. Due to its ability to deal with complex contexts, CIA is one of the most commonly used approaches to generate and analyze scenarios because of its ability to be combined with other methods that complement each other [21,22].

Interpretive structural modeling (ISM) aims to explain and reveal the interrelated structure of elements within complex systems. It classifies the analyzed system into interrelated nodes, reveals the inner structure and hierarchy of the system using Boolean logic operations and matrix transformation techniques, and visually presents it in the form of multilevel hierarchical directed graphs. The AISM adds hierarchical division principles as opposed to traditional ISM, building a set of rival hierarchical topologies [23]. This methodology not only preserves the strengths of ISM in revealing the structure of the system, but also provides more comprehensive and in-depth analyses by adopting an adversarial perspective. AISM pays particular attention to elements at different levels, namely, the activity elements. Systems with active elements are called extension variable systems, which have greater flexibility and adaptability. In this paper, to reduce subjectivity and uncertainty in the evaluation process, triangular fuzzy numbers are introduced to construct the TCIA-AISM scenario model. The most important system factors and the coupling relationship and conduction path between each factor are identified through scenario analysis. The initial probability of events can be changed to predict the development of other events.

The process of TCIA-AISM mainly consists of the following steps: construction of event sets, expert assessment, calculation of cross-influence, analysis of hierarchical relationships between events, and scenario analysis, as shown in Figure 1.

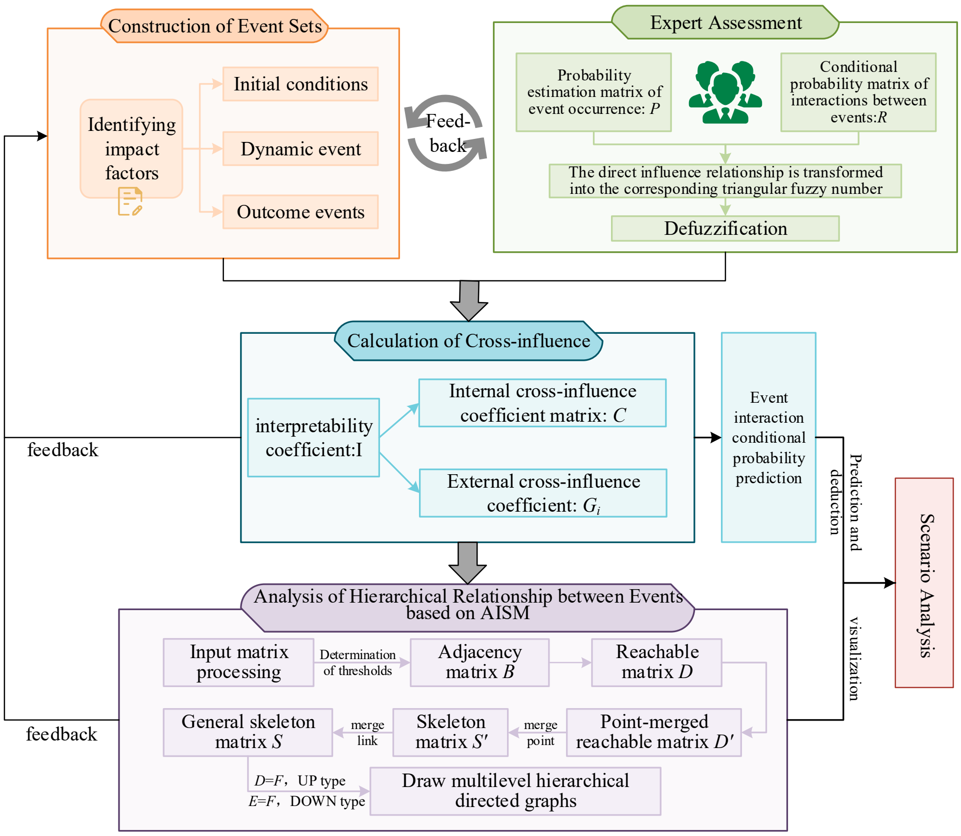


Figure 1. TCIA-AISM method flowchart.

2.1. Construction of Event Sets

The extracted events are categorized into three types: initial conditions (IC_i), dynamic events (DE_i), and outcome events (OE_i) [24].

Initial conditions: Events that exist before the onset of a risk event, as manifested in the underlying conditions or environment in which the supply chain operates. The probability of occurrence of the initial conditions is only affected by the interaction between the initial conditions.

Dynamic events: The core set of events associated with a critical incident after it occurs. They can be disruptions brought about by the risk event as well as countermeasures taken in response to the risk event.

Outcome events: The final outcome from a risk event that reflects the combined effects of initial conditions and dynamic events.

In addition to this, external events refer to other events that are related to risk but not chosen. This is an important criterion for determining rationality and efficacy.

2.2. Expert Assessment

(1) The expert determines the probability of an event occurring and the event interaction probability, and obtains the probability estimation matrix P and interaction conditional matrix R, $P = (P_i)_{N\times 1}$, $R = \left(R_{ij}\right)_{N\times N}$.

(2) Use fuzzy processing to transform the direct influence relationship into the corresponding triangular fuzzy number, as shown in Table 1.

Table 1. Influence degree and corresponding value table.

Semantic Interpretation	Triangular Fuzzy Number
Very high positive impact (VHP)	(0.80, 0.90, 1.00)
High positive impact (HP)	(0.70, 0.80, 0.90)
Medium positive impact (MP)	(0.60, 0.70, 0.80)
Low positive impact (LP)	(0.50, 0.60, 0.70)
No impact (N)	(0.40, 0.50, 0.60)
Low negative impact (LN)	(0.30, 0.40, 0.50)
Medium negative impact (MN)	(0.20, 0.30, 0.40)
High negative impact (HN)	(0.10, 0.20, 0.30)
Very high negative impact (VHN)	(0.00, 0.10, 0.20)

Triangular fuzzy number $\widetilde{T}^k = (l_{ij}^k, m_{ij}^k, u_{ij}^k)$, ${l_{ij}}^k$, ${m_{ij}}^k$ and ${u_{ij}}^k$ represent the lower, middle, and upper bounds of the fuzzy set, respectively, and $0 \le {l_{ij}}^k \le {m_{ij}}^k \le {u_{ij}}^k$, k = 1, 2, ..., K, where K is the expert number, and l and u are used to represent the ambiguity. When the difference between u-l increases, it means that the range of possible values of the fuzzy number becomes wider, that is, the value of x has non-zero membership in a wider interval. This increases the uncertainty of the value of x, and the fuzziness of x increases. The membership function of a triangular fuzzy number is defined as shown in Equation (1) [25].

$$\mu_T(x_{ij}^k) = \begin{cases} 0 & x_{ij}^k \notin [l_{ij}^k, u_{ij}^k] \\ \frac{x_{ij}^k - l_{ij}^k}{m_{ij}^k - l_{ij}^k} & l_{ij}^k \le x_{ij}^k \le m_{ij}^k \\ \frac{u_{ij}^k - x_{ij}^k}{u_{ij}^k - m_{ij}^k} & m_{ij}^k \le x_{ij}^k \le u_{ij}^k \end{cases} \tag{1}$$

The Converting Fuzzy numbers into Crisp Scores (CFCS) method was used to defuzzify the expert evaluations in the following steps [26,27].

(1) Normalization of initial data.

$$yl_{ij}^k = \frac{l_{ij}^k - \min l_{ij}^k}{\Delta_{\min}^{\max}} \tag{2}$$

$$ym_{ij}^k = \frac{m_{ij}^k - \min l_{ij}^k}{\Delta_{\min}^{\max}} \tag{3}$$

$$yu_{ij}^k = \frac{u_{ij}^k - \min l_{ij}^k}{\Delta_{\min}^{\max}} \tag{4}$$

where $\Delta_{\min}^{\max} = \max u_{ij}^k - \min l_{ij}^k$.

(2) Normalization of the left and right boundary values (yls_{ij}^k,yus_{ij}^k).

$$yls_{ij}^k = \frac{ym_{ij}^k}{1 + ym_{ij}^k - yl_{ij}^k} \tag{5}$$

$$yus_{ij}^k = \frac{yu_{ij}^k}{1 + yu_{ij}^k - ym_{ij}^k} \quad (6)$$

(3) Calculate the total normalized point estimate.

$$y_{ij}^k = \frac{[yls_{ij}^k(1 - yls_{ij}^k) + (yus_{ij}^k)^2]}{[1 - yls_{ij}^k + yus_{ij}^k]} \quad (7)$$

(4) Calculate the point estimate of expert k.

$$v_{ij}^k = \min l_{ij}^k + y_{ij}^k \Delta_{\min}^{\max} \quad (8)$$

(5) Calculate the average point estimate of the expert group.

$$v_{ij} = (\frac{1}{K})\sum_{k=1}^{K} v_{ij}^k \quad (9)$$

2.3. Calculation of Cross-Influence

When calculating the internal cross-influence coefficients, as shown in Equation (10), and the internal cross-influence, matrix C is obtained [28,29].

$$C_{ij} = \frac{1}{1 - P_j}\left[\ln\left(\frac{R_{ij}}{1 - R_{ij}}\right) - \ln\left(\frac{P_i}{1 - P_i}\right)\right] \quad (10)$$

Here, the value of C_{ij} represents the degree and direction of influence between events; a positive value of C_{ij} indicates that event j promotes the occurrence of event i; a negative value of C_{ij} indicates that event j promotes the occurrence of event i; P_i and P_j denote the probability of occurrence of event i and event j; R_{ij} represents the degree to which the occurrence of event j affects the occurrence of event i.

The external cross-influence coefficient is further determined, as shown in Equation (11).

$$G_i = \ln\left(\frac{P_i}{1 - P_i}\right) - \sum_{k \neq i}^{N} C_{ik} P_k \quad (11)$$

where N is the total number of events, and G_i represents the external impact coefficient of the i-th event.

To evaluate the reasonableness and interpretability of the event set, the interpretability coefficient of the constructed model is calculated, as shown in Equation (12).

$$\mathrm{I} = \frac{\sum|C_{ij}|}{\sum|C_{ij}| + \sum|G_i|} \quad (12)$$

When $\mathrm{I} \geq 80\%$, based on the Pareto principle, the established event set is considered to be fully feasible.

2.4. Analysis of Hierarchical Relationship Between Events Based on AISM

The cross-influence matrix C is the initial input to the AISM, which is used to visualize and analyze the internal correlations and conduction paths between events. The adversarial relationship-directed graphs formed by the AISM help in discovering the key impact events.

2.4.1. Processing Input Matrix

The values in the cross-influence matrix are positive and negative, and the AISM model requires that the values in the matrix cells be changed to positive ones. The matrix FH is obtained by calculation, as shown in Equations (13) and (14).

$$r_{ij} = \begin{cases} c_{ij}, \text{ event } j \rightarrow \text{ event } i \text{ positive effect} \\ 0, \text{ event } j \rightarrow \text{ event } i \text{ no effect} \\ -c_{ij}, \text{ event } j \rightarrow \text{ event } i \text{ negative effect} \end{cases} \quad (13)$$

$$FH = \left[r_{ij}\right]^T \quad (14)$$

Events i and j with positive impacts change their elements to (+i, +j) and ($-i$, $-j$); events i and j with negative impacts change their elements to ($-i$, +j) and (+i, $-j$), as shown in Table 2.

Table 2. Matrix conversion method.

	Occurrence of Event (+*i*)	**Nonoccurrence of Even (−*i*)**
Occurrence of event (+i)	c_{ij}	$-c_{ij}$
Nonoccurrence of event ($-i$)	$-c_{ij}$	c_{ij}

To reduce the noise impact of the CIA computation results, a suitable scale for the cross-influence transformation needs to be chosen. Use Formula (15) to convert the matrix FH to the adjacency matrix B.

$$B = \left[a_{ij}\right] = \begin{cases} 1, r_{ji} \geq \lambda \\ 0, r_{ji} < \lambda \end{cases} \quad (15)$$

Here, λ indicates the threshold intercept scale.

Take the adjacency matrix B as the AISM input matrix, and the reachability matrix D is computed using Equation (16).

$$(B + I)^{k-1} \neq (B + I)^k = (B + I)^{k+1} = D \quad (16)$$

Here, k is the number of matrix self-multiplications; I is the unit matrix.

2.4.2. Division of Hierarchy

For reachable matrices, the reachable set D, the leading set E, and the common set F are formed. The reachable set and antecedent set can display the relationship among events, but cannot visualize the level in which the events are placed, so it is necessary to extract the events according to the principle of hierarchy extraction and then divide the levels. The UP-type hierarchy is extracted on a result-first basis, when F (a_{ij}) = D (a_{ij}), and the event is removed and put at the top of the system; the DOWN-type hierarchy is extracted on a cause-first basis, and when F (a_{ij}) = E (a_{ij}), the event is removed and put at the bottom of the system.

2.4.3. Draw Multilevel Hierarchical Directed Graphs

The SCC algorithm of Tarjan is used to merge the reachable matrix, and the point-merged reachable matrix D' and skeleton matrix S' are obtained, as shown in Equation (17).

$$S' = D' - (D' - I)^2 - I \quad (17)$$

Here, I is the unit matrix. The general skeleton matrix S is obtained by substituting the circuit elements into the skeleton matrix S'.

The general skeleton matrix largely reduces the complexity of the system. Multi-level hierarchical directed graphs are drawn based on the relationship between the elements to visualize the key events.

2.5. Probability Derivation

When the probability of occurrence of the event set changes, Formula (18) can be used as an important basis for deriving the probability of occurrence of other events.

$$P_i' = \frac{1}{1 + \exp(-G_i - \sum_{k \neq i}^{N} C_{ik} P_k')} \quad (18)$$

Here, C_{ik} is the coefficient of the impact of event k on event i; $P_k{}'$ is the initial probability of event k occurring; and $P_i{}'$ is the probability of event i occurring because of other event disturbances.

Based on the probability of the predicted results, the scenario is deduced to depict the evolution of supply chain resilience.

3. Case Study

3.1. Case Background

This paper analyzes the supply chain crisis triggered by the interruption of needle roller supply, as an example of enterprise G. Enterprise G is a well-known supplier of bearings and auto parts. A company in Shanghai, as the only needle roller raw material supplier of G enterprise, was required by the relevant departments to implement "power cut and production suspension, dismantling of related equipment" since 10 September, 2017, due to environmental protection issues, which directly led to the interruption of the needle roller supply of G enterprise. The shortage of needle rollers will lead to the total suspension of production of more than 200 models at 49 auto manufacturers. It is estimated that the loss could be as high as RMB 300 billion. At the same time, the shutdown of the vehicle factory will also lead to huge economic losses, including production stagnation, order cancellation, customer loss, and so on. As G enterprise is the supplier of many automobile manufacturers, its shortage will directly lead to the production of downstream enterprises, which will affect the stability of the entire automobile industry chain.

3.2. Identifying Impact Factors

The event set was constructed grounded on similar cases that have occurred, as well as literature analyzing the factors that influence the resilience of the bearing supply chain. Experts were invited to discuss and judge the scientificity and representativeness of the selected event set. Twenty-three events were finally identified, including 10 initial conditions, eight dynamic events, and five outcome events, as shown in Table 3.

Table 3. Event sets.

Event Category	Number	Event Set	Definition	
Initial conditions	IC_1	Accuracy of market demand forecasting	The ability of a company to accurately predict the future supply, demands, and prices of products in the supply chain based on historical data, market trends, consumer behavior, and other information.	[30,31]
	IC_2	Risk awareness	Enterprises can warn, plan, assess, avoid, and control risk before it strikes.	[30,32]
	IC_3	Supply chain visibility	Degree of comprehensive supervision and control of the entire supply chain operation process with the help of a visual information system.	[31–33]
	IC_4	Contingency planning capacity	The ability of an organization to rapidly establish emergency response mechanisms through a series of measures such as supply chain reconfiguration and design, information monitoring, and technology maintenance in the face of emergencies.	[31,34,35]
	IC_5	Structural stability of supply chain network	Ordered relationships and structures are formed between firm members to have the ability to withstand the disruptions of competition and uncertainty, mainly in terms of supply chain member reputation as well as supply chain complexity.	[33,36,37]
	IC_6	The basic strength of supply chain members	Including the level of facilities, market share, financial strength, and so on.	[32,35,37]

Table 3. *Cont.*

Event Category	Number	Event Set	Definition	
Initial conditions	IC_7	Staff personal quality and experience accumulation	The comprehensive ability shown by employees in their work and the knowledge and experience accumulated in long-term work.	[32,35,37]
	IC_8	Redundancy	Stockpiling critical resources and replicating key components or procedures in the supply chain to ensure that backup systems are available in the event of disruptions or failures, such as having multiple suppliers, alternate transportation routes, storage facilities, and alternative processing plants.	[32,35,36]
	IC_9	Ability to learn and grow	It mainly includes learning ability and innovation ability. Learning ability is the ability to learn lessons and share experiences in a timely and effective manner after the occurrence of adverse events. Innovation ability is the ability to optimize the management technology level of supply chain enterprises and grasp the industry technology update.	[32,35,36]
	IC_{10}	Adverse external shocks	These include man-made disasters, natural events, and international conflicts. Man-made disasters include global pandemics, economic setbacks, technological change, policy changes, and fires. Natural disasters such as earthquakes, floods, and heavy rains. International conflict refers to the competition and confrontation between actors in the international community in terms of interests, power, status, and resources.	[34,37,38]
Dynamic events	DE_1	Changes in the structure of market demand	Shifts in the types, proportions, and preferences of consumer demand for goods or services in the marketplace.	[35,37–39]
	DE_2	Emergency change of order information	Sudden modification requests from customers or the market for orders already placed involve adjustments to product specifications, quantities, delivery times, and other key information.	[37,39]
	DE_3	Miscommunication	A situation in which errors, omissions, or delays in the transmission of information result in the recipient failing to obtain the original information in an accurate and timely manner.	[33,40]
	DE_4	Problems with critical resources	Includes shortages and defects, inadequate supply of raw materials, spare parts, manpower, etc., and failure of acquired resources to meet established standards or requirements in terms of quality.	[38,40]
	DE_5	Disorganized production schedule	Due to the imbalance of resource allocation and other factors, the execution of the original production plan was blocked, the production schedule was seriously deviated, and the product delivery was delayed.	[40,41]
	DE_6	Sudden damage to equipment	An emergency in which critical equipment malfunctions or fails in the course of production or operations without anticipation or prior warning, resulting in interruption of production or disruption of operations.	[30,41]
	DE_7	Distribution anomaly	Deviations from plans or expectations in the distribution process, including but not limited to problems such as delays, errors, damage, or loss.	[30,38,41]
	DE_8	Unreliable partners	The partner fails to meet its commitments or responsibilities.	[30,41]
Outcome Events	OE_1	Supply chain disruption	During the operating process in the supply chain, an unexpected event occurs suddenly in one or more parts of the supply chain, which leads to the obstruction of the logistics, information flow, or capital flow in the supply chain, and then affects the normal operation of the whole supply chain.	[34,38,39]
	OE_2	Temporary shutdown of production lines	The production line suspended production activities for some reason, but measures were taken to resolve the problem and normal production processes and capacity were resumed eventually.	[34,38]
	OE_3	Cumulative chain breaks	In the supply chain operation process, the gradual accumulation of several small problems forms a potential risk, which has a limited impact on the supply chain operation in the short term, but once it accumulates to a certain extent, it may lead to the disruption or serious obstruction of the supply chain as a whole.	[34]
	OE_4	Flexible supply chain response	When facing internal and external changes, the supply chain system can quickly adjust its strategy and optimize resource allocation to ensure smooth supply chain operation.	[39]
	OE_5	Significant economic loss of the enterprise	A situation in which an enterprise suffers huge financial losses due to a sharp decline in asset value and significant deterioration in financial condition due to internal and external factors.	[38,42]

3.3. Model Analysis

To quantify the interactions between events, based on the number of events, the team needed to make 326 estimates, as shown in Figure 2. After the semantic transformation of evaluation and the defuzzification of triangular fuzzy numbers, the probability estimation matrix P and the interaction condition matrix R are obtained, which are used as inputs to the cross-influence model. According to Formulas (10) and (11), the internal cross-influence coefficient and external cross-influence coefficient are calculated, respectively. Taking the cross-influence coefficients to their absolute values, the ranking of the degree of influence of the initial conditions and dynamic events on the outcome events is shown in Table 4. Formula (12) is used to evaluate the rationality and interpretability of the set of events.

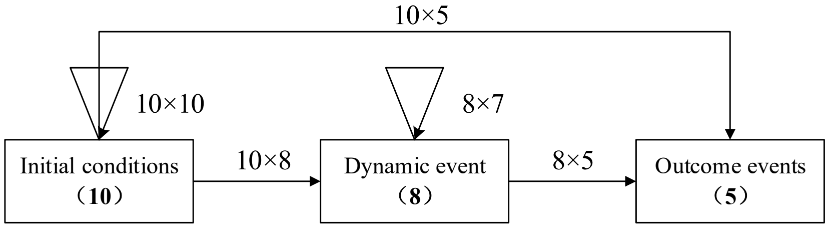


Figure 2. Graph of the number of events and the number of estimates required.

Table 4. Sequence of cross-influence of initial conditions and dynamic events on outcome events.

Sequence	**OE$_1$**		**OE$_2$**		**OE$_3$**		**OE$_4$**		**OE$_5$**	
1	IC$_3$	3.243	DE$_7$	3.874	DE$_4$	3.549	IC$_5$	3.243	IC$_{10}$	3.243
2	IC$_{10}$	3.243	IC$_{10}$	2.966	DE$_8$	2.966	IC$_3$	2.966	IC$_4$	2.051
3	IC$_5$	2.966	DE$_5$	2.966	IC$_2$	2.711	IC$_4$	2.966	DE$_4$	2.051
4	IC$_6$	2.485	DE$_6$	2.966	DE$_7$	2.485	IC$_{10}$	2.711	DE$_7$	2.051
5	DE$_6$	2.485	DE$_3$	2.262	IC$_{10}$	2.051	IC$_6$	2.485	DE$_8$	2.051
6	DE$_8$	2.485	DE$_2$	2.051	DE$_2$	1.859	IC$_9$	2.485	IC$_1$	1.666
7	IC$_4$	2.262	DE$_8$	1.859	DE$_3$	1.859	IC$_1$	2.262	IC$_5$	1.666
8	DE$_5$	2.262	IC$_5$	1.666	IC$_5$	1.666	DE$_7$	2.262	DE$_3$	1.666
9	DE$_2$	2.051	IC$_6$	1.666	IC$_6$	1.666	IC$_7$	2.051	DE$_5$	1.666
10	DE$_3$	2.051	IC$_8$	1.666	IC$_7$	1.666	IC$_8$	2.051	IC$_2$	1.309
11	DE$_7$	2.051	DE$_4$	1.666	DE$_5$	1.666	DE$_3$	2.051	IC$_3$	1.309
12	IC$_1$	1.666	IC$_1$	1.480	IC$_4$	1.480	DE$_5$	2.051	IC$_9$	1.309
13	DE$_4$	1.666	IC$_2$	1.480	IC$_3$	1.309	DE$_8$	2.051	DE$_6$	1.309
14	IC$_8$	1.480	IC$_3$	1.480	IC$_8$	1.309	IC$_2$	1.859	IC$_7$	1.133
15	IC$_9$	1.309	IC$_7$	1.480	IC$_9$	1.133	DE$_4$	1.666	IC$_8$	1.133
16	IC$_2$	1.133	DE$_1$	1.309	DE$_1$	0.962	DE$_6$	1.666	DE$_2$	1.133
17	IC$_7$	1.133	IC$_4$	0.794	DE$_6$	0.962	DE$_1$	1.480	IC$_6$	0.962
18	DE$_1$	0.803	IC$_9$	0.637	IC$_1$	0.794	DE$_2$	1.480	DE$_1$	0.962

$$|\text{Internal event impacts}| = \sum|C_{ij}| = 465.1833 \quad (19)$$

$$|\text{External event impacts}| = \sum|G_i| = 88.6129 \quad (20)$$

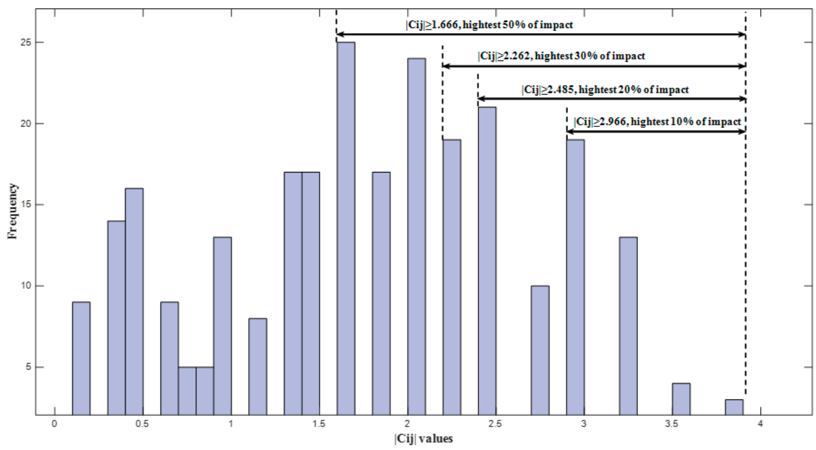
$$|\text{Total impacts}| = \sum|C_{ij}| + \sum|G_i| = 553.7962 \quad (21)$$

$$\frac{|\text{ Internal event impacts }|}{|\text{ Total impacts }|} = 84\% \quad (22)$$

$$\frac{|\text{ External event impacts }|}{|\text{ Total impacts }|} = 16\% \quad (23)$$

Through calculation, the interpretability coefficient of the model is more than 80%, and the proportion of the internal events' influence is far larger than the proportion of the external events' influence, which comprehensively includes events that affect resilience, indicating that the model is feasible.

AISM analysis can be used to observe logical changes between events by selecting different thresholds [43]. If the value of $|C_{ij}|$ is more than or equal to the limit value, it indicates that there is a direct connection from node *j* to node *i* [44]. These values will be used as split points in the directed graph; for example, if we use values with a cumulative frequency of 90% as split points, the directed graph contains the 10% highest impact. The histogram of the absolute frequency distribution of C_{ij} is drawn, as shown in Figure 3. The values of $|C_{ij}|$ are sorted from high to low, and the strong relationships among the top 30% ($|C_{ij}| \geq 2.262$) and 10% ($|C_{ij}| \geq 2.966$) are selected as the limit values to construct a new cross-influence matrix, respectively. The reachable matrix is calculated, and multi-level hierarchical digraphs of UP and DOWN types are drawn according to the hierarchical extraction principle of result first and cause first, as shown in Figures 4 and 5. In the graphs, different shapes represent events with different influence directions between them. A positive influence is seen between two events of the same shape, while a negative influence is between two events of different shapes. The direction of the arrow represents the direction of the influence.



Percentile of highest to lowest absolute values of $|C_{ij}|$

percentile	$\|C_{ij}\|$
90	2.966
80	2.485
70	2.262
50	1.666

Figure 3. Histogram of $|C_{ij}|$ distribution.

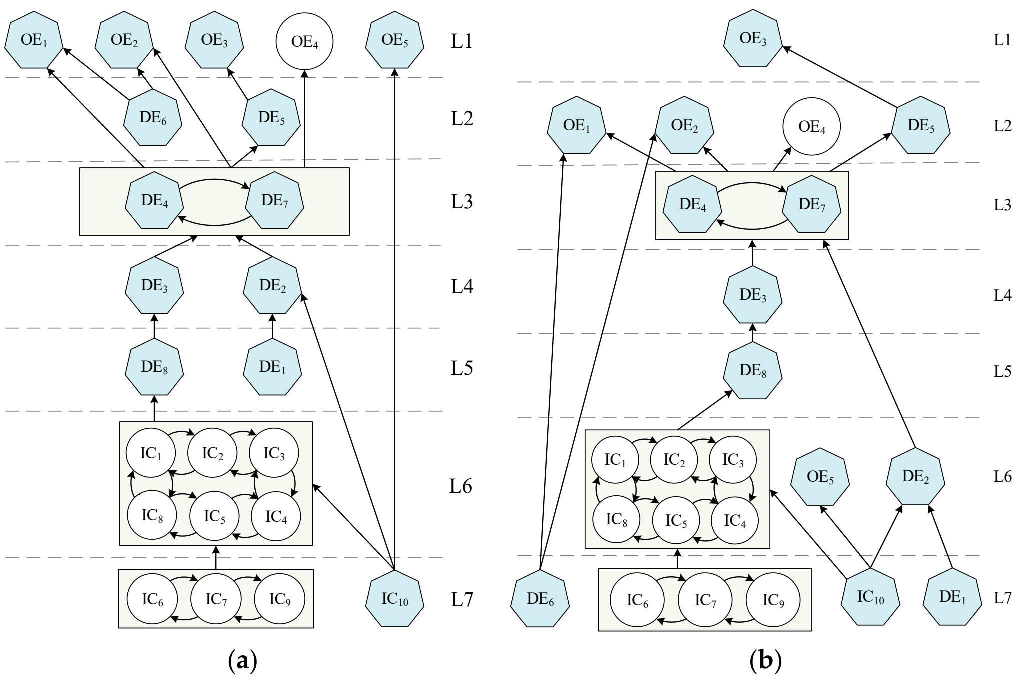
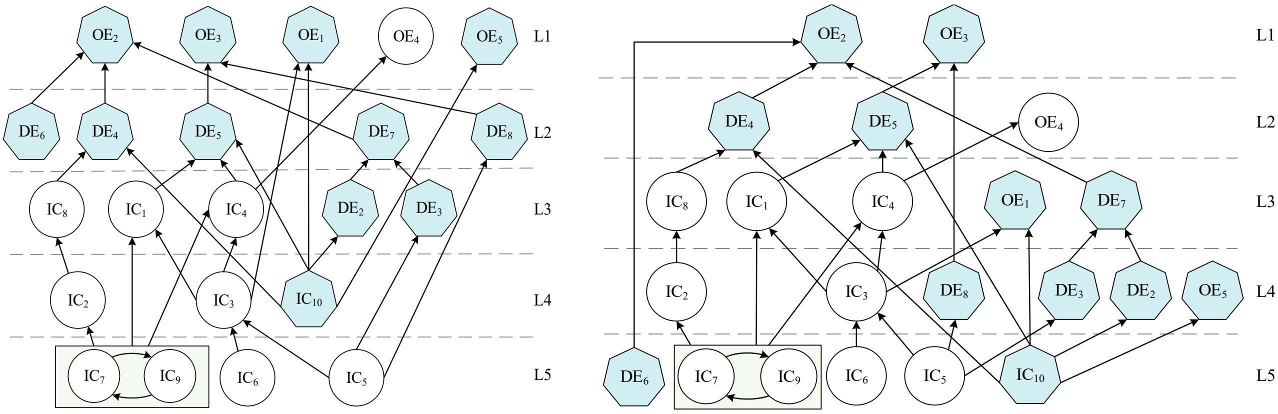


Figure 4. Multilevel hierarchical directed graphs of $|C_{ij}| \geq 2.262$—with 30%. (**a**) UP-type (30%); (**b**) DOWN-type (30%).



(**a**) (**b**)

Figure 5. Multilevel hierarchical directed graphs of $|C_{ij}| \geq 2.966$—with 30%. (**a**) UP-type (10%); (**b**) DOWN-type (10%).

The multilevel hierarchical digraph built in Figure 4 contains more causality than in Figure 5, and the top 30% of the multilevel hierarchical digraphs have seven levels. This level of directed hierarchy has three micro-scene sets in the structure {IC_6, IC_7, IC_9}, {IC_1, IC_2, IC_3, IC_4, IC_5, IC_8} and {DE_4, DE_7}, indicating that these events strongly influence each other and usually occur together. Although the UP-type and DOWN-type structure diagrams have a consistent number of layers, the layers in which the events are located are not the same. The activity elements include OE_1, OE_2, OE_4, OE_5, DE_1, DE_2 and DE_6. The system is an extension variable system with stronger flexibility and adaptability. Based on the underlying logic of the hierarchical extraction principle, from the DOWN-type structure diagram, it can be seen that IC_6, IC_7, IC_9, IC_{10}, $DE_{1,}$ and DE_6 are the root causes that affect the resilience of the bearing supply chain, while the UP-type structure diagram shows that DE_5 and DE_6 are the dynamic events that most directly affect the outcome events. Therefore, we should start from the above events to improve the corresponding ability and find the corresponding solution measures.

Figure 5 provides more clarity on the specific impact pathways and underlying logic that lead to the outcome event, and intuitively shows the cascade effect and conduction path between the events. The relationship between DE_1 and other events is weakened when the threshold takes the value $|C_{ij}| \geq 2.966$, and DE_1 is less significant in the model and no longer appears as a key influencing factor. The hierarchy is also reduced to five levels due to changes in threshold values. The activity elements are OE_1, OE_4, OE_5, DE_2, DE_3, DE_6, DE_7, DE_8 and IC_{10}. Only {IC_7, IC_9} remain in the micro-scene, while the root cause removes DE_1 and adds IC_5. DE_4, DE_5, DE_6, DE_7, and DE_8 are the dynamic events that have the most direct impact on the outcome events. When decision-makers face unexpected events, through the conduction path diagram, they can be targeted at the current supply chain problems to take corresponding measures for emergency management, so as to effectively alleviate the crisis and ensure the stable operation of the supply chain.

3.4. Scenario Deduction

Stage 1 (Z_1): A company in Shanghai is the only supplier of needle rollers, which indicates that the structural stability of the supply chain network and redundancy of Enterprise G is insufficient to ensure that there are backup resources to replenish the supply of key raw materials promptly when it is inadequate. This company was asked to "cut off power, suspend production and dismantle related equipment" due to environmental protection problems, so the initial probability of events IC_5 and IC_8 is set to 0, and the initial probability of IC_{10} is set to 1. As a globally renowned first-tier supplier in the automotive industry, enterprise G is a strong enterprise, so the initial probability of event IC6 is set to 1.

As a well-known first-level supplier in the automotive industry, Company G has strong strength, and we set the initial probability of event IC_6 as 1.

Stage 2 (Z_2): After the incident, the supply of needle rollers was interrupted and key raw materials could not be delivered in time, resulting in the production plan being blocked, and the bearing production line of Enterprise G was forced to shut down, which in turn affected the production of downstream automobile manufacturing enterprises. Customer orders were canceled, customers were lost, and the estimated economic loss was up to hundreds of billions of RMB. We set the initial probability of events DE_2, DE_4, DE_5, DE_7, and DE_8 at this stage to 1.

Stage 3 (Z_3): Enterprise G responds proactively by utilizing the resources of its global network to actively search for alternative suppliers to ensure the supply of needle rollers. At the same time, urgent consultations are held with existing suppliers to explore possible solutions. Internal emergency adjustments are also made, including optimizing production plans and adjusting inventory strategies. We set the initial probability of events IC_3, IC_4, and IC_7 to 1, and the initial probability of DE_5 to 0.

The changes in the probability of events occurring in each phase are summarized as shown in Table 5. Using Equation (18), new probabilities of other events occurring in each stage can be predicted, as shown in Table 6. The probability changes of five outcome events are shown in Figure 6.

Table 5. Condition setting of bearing supply chain resilience scenario deduction.

Stage	Event Probability Setting
Z_1	$IC_5 = 0$, $IC_8 = 0$, $IC_6 = 1$, $IC_{10} = 1$, the remaining initial conditions, dynamic event probabilities are 0.5.
Z_2	$DE_2 = 1$, $DE_4 = 1$, $DE_5 = 1$, $DE_7 = 1$, $DE_8 = 1$, $IC_5 = 0$, $IC_8 = 0$, $IC_6 = 1$, $IC_{10} = 1$, the remaining initial conditions, dynamic event probabilities are 0.5.
Z_3	$IC_3 = 1$, $IC_4 = 1$, $IC_7 = 1$, $IC_9 = 1$, $DE_5 = 0$, $IC_5 = 0$, $IC_8 = 0$, $IC_6 = 1$, $IC_{10} = 1$, $DE_2 = 1$, $DE_4 = 1$, $DE_7 = 1$, $DE_8 = 1$, the remaining initial conditions, dynamic event probabilities are 0.5.

Table 6. Changes in event prediction probability.

Event	Z_1	Z_2	Z_3
IC_1	0.5	0.5	0.5
IC_2	0.5	0.5	0.5
IC_3	0.5	0.5	1
IC_4	0.5	0.5	1
IC_5	0	0	0
IC_6	1	1	1
IC_7	0.5	0.5	1
IC_8	0	0	0
IC_9	0.5	0.5	1
IC_{10}	1	1	1
DE_1	0.7360	0.5	0.5
DE_2	0.8652	1	1
DE_3	0.8916	0.5	0.5
DE_4	0.9683	1	1
DE_5	0.9681	1	0
DE_6	0.6468	0.5	0.5
DE_7	0.8255	1	1
DE_8	0.8462	1	1
OE_1	0.9310	0.9996	0.9020
OE_2	0.9102	0.9998	0.9906
OE_3	0.8429	0.9996	0.8319
OE_4	0.0595	0.0005	0.3510
OE_5	0.9269	0.9991	0.8874

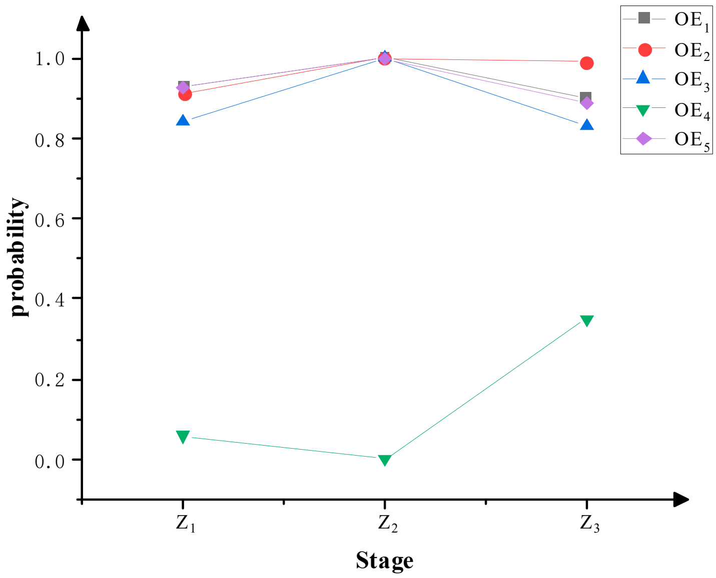


Figure 6. Plot of predicted probability changes of outcome events.

From Figure 6, it is clear that in Z_1, due to the failure of enterprise G to have a stable network structure and a certain amount of reserve, resulting in OE_1, OE_2, OE_3 and OE_5 probability of occurrence of more than 80%, the probability of the occurrence of OE4 is about 6%, which seriously affects the stability of the supply chain and security. In Z_2, the series of dynamic events brought about by the unexpected event makes the probability of the outcome event close to 1. At this time, the supply chain disruption, production line shutdown, and the enterprise suffering a significant economic loss are all in line with the actual situation. In Z_3, G company took a series of measures to deal with the interruption of the supply crisis of the needle roller supplier, and the positive response reduced the probability of the resulting event. Because the supply of needle rolling can not be completely restored in the short term, some production lines are still stopped, and the impact on production planning, customer delivery, and enterprise losses is still unavoidable. However, the responsiveness of the supply chain has increased significantly, which can mitigate some of the problems caused by emergencies, and the predicted value is in line with the actual situation.

To effectively address similar risks, the following assumptions are made to compare with the actual situation, and the probability changes of the event simulation are shown in Table 7 and Figure 7.

Table 7. Changes in probability of assumption compared to factual situation.

Event	Z_1	Y_1	Y_2
IC_1	0.5	0.5	0.5
IC_2	0.5	0.5	0.5
IC_3	0.5	0.5	1
IC_4	0.5	0.5	1
IC_5	0	0	0
IC_6	1	1	1
IC_7	0.5	0.5	1
IC_8	0	1	1
IC_9	0.5	0.5	1
IC_{10}	1	1	1
DE_1	0.7360	0.7360	0.5
DE_2	0.8652	0.8244	0.8244
DE_3	0.8916	0.8751	0.5

Table 7. *Cont.*

Event	Z_1	Y_1	Y_2
DE_4	0.9683	0.3884	0.3884
DE_5	0.9681	0.6687	0.6687
DE_6	0.6468	0.6468	0.5
DE_7	0.8255	0.6813	0.6813
DE_8	0.8462	0.8462	0.5
OE_1	0.9310	0.7543	0.1436
OE_2	0.9102	0.6570	0.4431
OE_3	0.8429	0.5917	0.2775
OE_4	0.0595	0.3298	0.9729
OE_5	0.9269	0.8033	0.3556

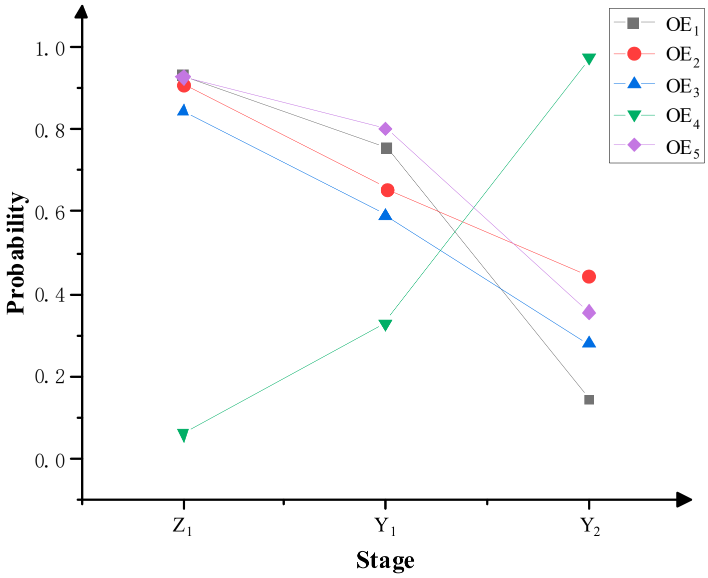


Figure 7. Plot of changes in assumed probabilities of outcome events.

Assumption 1 (Y_1): *The key cause of the supply chain disruption is the lack of redundancy in enterprise G and the lack of multiple suppliers for key resources. Assuming that the firm has alternate suppliers, the development of Firm G experiencing this crisis is simulated. This stage is set to remain consistent with Z_1, changing only the initial probability of IC_8 to 1.*

Assumption 2 (Y_2): *The simulation scenario does not occur, so the probability of the dynamic event uses the value obtained from the Y_1 prediction. Since adverse external shocks include the effects of natural disasters, and so on, only the effects caused by policy changes on the dynamic events are considered, and the initial probabilities of DE_1, DE_3, DE_6, and DE_8 are set to be 0.5, and the probabilities of the remaining initial conditions are kept consistent with Z_3.*

From the results, it can be seen that having a certain amount of spare reserves can be effective in resolving crises, with the probability of supply chain disruption dropping to 0.1436, the probability of being able to respond flexibly reaching 0.9729, and the probability of the enterprise suffering a loss dropping significantly.

4. Conclusions

Based on the analysis of the disruption event at Enterprise G and similar cases, an analysis of the literature was conducted to analyze other factors affecting the resilience of the bearing supply chain, and experts were invited to discuss the determination of the event set. The following conclusions are drawn from the analysis and research.

(1) Introducing triangular fuzzy quantitative expert evaluation, effectively expressing the complex relationship between evaluation indicators, more comprehensively considering the mutual influence of factors, and making the evaluation results more scientific and reasonable.
(2) Taking the intersection of the multilevel recursive order-directed graphs of the top 30% and top 10% of impact intensities. It is concluded that the basic strength of supply chain members, staff personal quality and experience accumulation, ability to learn and grow, adverse external shocks, and sudden damage to equipment are the root causes affecting the resilience of the bearing supply chain; a disorganized production schedule and sudden damage to equipment are the dynamic events that have the most direct impact on the outcome events.
(3) Applying enterprise G interruption events to the TCIA-AISM model for scenario inference. The predicted results of the model are consistent with the realistic results of Enterprise G interruption events. The model is feasible and effective. Through further assumptions, the simulation deduction of the fundamental response measures for risk events shows that the effect of ensuring the security and sustainability of the supply chain is significantly improved.

This paper establishes the TCIA-AISM scenario model, which not only enriches the field of resilience research but also provides a new analytical method that helps scholars to better specify the root causes that affect the occurrence of outcomes and clarify the cascading effects and transmission paths between events. In practical application, the probability of events occurring under different scenarios can be varied to predict possible consequences and develop corresponding risk response measures accordingly. Although bearing enterprises in different countries differ in many aspects, they exhibit significant commonalities in terms of the key capabilities that determine supply chain resilience, the impact of risk events on the various components of supply chain management, and the consequences that can be triggered by supply chain disruptions. Therefore, this methodology is feasible and effective in addition to the enterprise G disruptions, and can be applied to other international cases.

For future research, the focus could be on expanding the application scenarios of the methodology to provide more detailed and accurate predictions of outcome events by taking into account multifaceted factors such as cultural policy differences between countries and diverse risk attitudes among decision-makers, in order to make the model more adequate and precise and able to adapt to more complex and variable systems.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16209069/s1, Table S1: Cross-impact matrix; Table S2: Direction of influence.

Author Contributions: Conceptualization, F.L. (Feng Lyu); methodology, F.L. (Feng Lyu) and F.L. (Fen Liu); software, F.L. (Fen Liu); validation, F.L. (Feng Lyu), F.L. (Fen Liu) and S.Z.; formal analysis, F.L. (Fen Liu); investigation, F.L. (Fen Liu); data curation, F.L. (Feng Lyu), F.L. (Fen Liu) and S.Z.; writing—original draft preparation, F.L. (Feng Lyu) and F.L. (Fen Liu); writing—review and editing, F.L. (Feng Lyu) and F.L. (Fen Liu); visualization, F.L. (Fen Liu); supervision, F.L. (Feng Lyu); project administration, F.L. (Feng Lyu) and Z.Z.; funding acquisition, F.L. (Feng Lyu) and Z.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by "National Social Science Foundation Program of China, grant number 20BJY097" and "National Key Research and Development Program Projects of China, grant number 2020YFB1713500".

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the Supplementary Materials.

Acknowledgments: The authors gratefully acknowledge the support of the Foundation program and the helpful comments and suggestions of the reviewers, which improved the presentation.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Zhang, T.; Wang, H. Quantile regression network-based cross-domain prediction model for rolling bearing remaining useful life. *Appl. Soft Comput.* **2024**, *159*, 111649. [CrossRef]
2. Xu, F.; Ding, N.; Li, N.; Liu, L.; Hou, N.; Xu, N.; Guo, W.; Tian, L.; Xu, H.; Wu, C.-M.L.; et al. A review of bearing failure Modes, mechanisms and causes. *Eng. Fail. Anal.* **2023**, *152*, 107518. [CrossRef]
3. Manan, B.R.; Hirenkumar, J. Categorical framework for implementation of industry 4.0 techniques in medium-scale bearing manufacturing industries. *Mater. Today Proc.* **2022**, *65*, 3531–3537.
4. Christopher, M.; Peck, H. Building the Resilient Supply Chain. *Int. J. Logist. Manag.* **2004**, *15*, 1–13. [CrossRef]
5. Wu, H.; Li, G.; Zheng, H. How Does Digital Intelligence Technology Enhance Supply Chain Resilience? Sustainable Framework and Agenda. *Ann. Oper. Res.* **2024**, *6*, 1–23. [CrossRef]
6. Ali, A.; Mahfouz, A.; Arisha, A. Analysing supply chain resilience: Integrating the constructs in a concept mapping framework via a systematic literature review. *Supply Chain. Manag.* **2017**, *22*, 16–39. [CrossRef]
7. Wieland, A.; Wallenburg, C.M. The influence of relational competencies on supply chain resilience: A relational view. *Int. J. Phys. Distr. Logist. Manag.* **2013**, *43*, 300–320. [CrossRef]
8. Ivanov, D.A.; Sokolov, B.; Dolgui, A. The Ripple effect in supply chains: Trade-off 'efficiency-flexibility-resilience' in disruption management. *Int. J. Prod. Res.* **2014**, *52*, 2154–2172. [CrossRef]
9. Brandon, J.E.; Squire, B.; Autry, C.W.; Petersen, K. A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness. *J. Supply Chain. Manag.* **2014**, *50*, 55–73. [CrossRef]
10. Tukamuhabwa, B.R.; Stevenson, M.; Busby, J.; Zorzini, M. Supply chain resilience: Definition, review and theoretical foundations for further study. *Int. J. Prod. Res.* **2015**, *53*, 5592–5623. [CrossRef]
11. Chowdhury, M.H.; Quaddus, M. Supply chain readiness, response and recovery for resilience. *Supply Chain. Manag.* **2016**, *21*, 709–731. [CrossRef]
12. Ge, R.; Bao, H. Digital transformation and resilience of supply chain in manufacture listed firms: A backward spillover effects in the vertical supply chain relationship. *Financ. Res. Lett.* **2024**, *65*, 105516. [CrossRef]
13. Atieh Ali, A.A.; Sharabati, A.A.A.; Allahham, M.; Nasereddin, A.Y. The Relationship between Supply Chain Resilience and Digital Supply Chain and the Impact on Sustainability: Supply Chain Dynamism as a Moderator. *Sustainability* **2024**, *16*, 3082. [CrossRef]
14. Zheng, T.; Zhao, G.; Chu, S. A Study on the Impact of External Shocks on the Resilience of China's Grain Supply Chain. *Sustainability* **2024**, *16*, 956. [CrossRef]
15. Zhu, Y.; Zhang, C.; Fang, J.; Miao, Y. Paths and strategies for a resilient megacity based on the water-energy-food nexus. *Sustain. Cities Soc.* **2022**, *82*, 103892. [CrossRef]
16. Ishii, N.; Ohba, M. Quantitative evaluation of an information network in a supply chain. *Int. J. Prod. Econ.* **2023**, *261*, 108889. [CrossRef]
17. Sabouhi, F.; Jabalameli, M.S.; Jabbarzadeh, A. An optimization approach for sustainable and resilient supply chain design with regional considerations. *Comput. Ind. Eng.* **2021**, *159*, 107510. [CrossRef]
18. Lotfi, R.; Kargar, B.; Rajabzadeh, M.; Hesabi, F.; Özceylan, E. Hybrid Fuzzy and Data-Driven Robust Optimization for Resilience and Sustainable Health Care Supply Chain with Vendor-Managed Inventory Approach. *Int. J. Fuzzy Syst.* **2022**, *24*, 1216–1231. [CrossRef]
19. Xu, B.; Liu, W.; Li, J.; Yang, Y.; Wen, F.; Song, H. Resilience Measurement and Dynamic Optimization of Container Logistics Supply Chain under Adverse Events. *Comput. Ind. Eng.* **2023**, *180*, 109202. [CrossRef]
20. Bañuls, V.A.; Turoff, M.; Hiltz, S. Collaborative Scenario Modelling in Emergency Management through Cross-Impact. *Technol. Forecast. Soc. Chang.* **2013**, *80*, 1756–1774. [CrossRef]
21. Bañuls, V.A.; Turoff, M. Scenario construction via Delphi and cross-impact analysis. *Technol. Forecast. Soc. Chang.* **2011**, *78*, 1579–1602. [CrossRef]
22. Mehrolhassani, M.H.; Setayesh, M.; Yazdi-Feyzabadi, V.; Rahimisadegh, R. Identification of Drivers and Affecting Factors in the Future of Persian Medicine: The Cross-Impact Analysis Method. *Eur. J. Integr. Med.* **2024**, *65*, 102316. [CrossRef]
23. Xu, W.; Lu, Y.; Proverbs, D. An evaluation of factors influencing the vulnerability of emergency logistics supply chains. *Int. J. Logist. Res. Appl.* **2023**, *27*, 1891–1924. [CrossRef]
24. Turoff, M.; Bañuls, V.A. Major extensions to Cross-Impact Analysis. In Proceedings of the International Conference on Information Systems for Crisis Response and Management, Lisbon, Portugal, 8–11 May 2011.
25. Chandrasekar, S.; Saranyaa, P.; Nagarajan, D.; Pamučar, D. Triangular intuitionistic fuzzy number based backorder and lost sale in production, remanufacturing and inspection process. *Expert Syst. Appl.* **2023**, *240*, 122261.

26. Gadekar, R.; Sarkar, B.; Gadekar, A. Key performance indicator based dynamic decision-making framework for sustainable Industry 4.0 implementation risks evaluation: Reference to the Indian manufacturing industries. *Ann. Oper. Res.* **2022**, *318*, 189–249. [CrossRef]
27. Chen, X.; Qiao, W. A hybrid STAMP-fuzzy DEMATEL-ISM approach for analyzing the factors influencing building collapse accidents in China. *Sci. Rep.* **2023**, *13*, 19745. [CrossRef]
28. Guo, L.; Liang, J.; Chen, T.; Gao, Y.; Yang, Z. Scenario-Driven Methodology for Cascading Disasters Risk Assessment of Earthquake on Chemical Industrial Park. *Processes* **2023**, *11*, 32. [CrossRef]
29. Wang, R.; Cui, S.; Gao, M. Systematic scenario modeling for priority assessment of sustainable development goals in China under interaction and uncertainty. *Environ. Dev. Sustain.* **2024**, *2*, 1–36. [CrossRef]
30. Wicaksono, T.; Illés, C.B. From resilience to satisfaction: Defining supply chain solutions for agri-food SMEs through quality approach. *PLoS ONE* **2022**, *17*, e0263393. [CrossRef]
31. Ingra, V.F.; Silvio, L.S.A.; Davi, S.; Enzo, M.F. Visibility model for enhancing supply chains resilience. *IFAC-PapersOnLine* **2022**, *55*, 2521–2525.
32. Liu, J.; Wu, J.; Gong, Y. Maritime supply chain resilience: From concept to practice. *Comput. Ind. Eng.* **2023**, *182*, 109366. [CrossRef]
33. Ethan, N.; David, G.R.; Ivan, R. Supply chain resilience: When the recipe is more important than the ingredients for managing supply chain disruptions. *Int. J. Prod. Econ.* **2024**, *272*, 109236.
34. Funlade, S.; Patrick, B.; Albert, T.; Janya, C.; Sreejith, B.; Mustafa, M. Prioritising Visibility Influencing Factors in Supply Chains for Resilience. *Procedia Comput.* **2023**, *217*, 1589–1598.
35. Lin, M.; Ren, Y.; Feng, C.; Li, X. Analyzing resilience influencing factors in the prefabricated building supply chain based on SEM-SD methodology. *Sci. Rep.* **2024**, *14*, 17393. [CrossRef]
36. Farhad, H.; Ripon, K.C.; Alireza, A. Evaluating supply chain network resilience considering disruption propagation. *Comput. Ind. Eng.* **2023**, *183*, 109531.
37. Zhong, J.; Cheng, H.; Jia, F. Supply chain resilience capability factors in agri-food supply chains. *Oper. Manag. Res.* **2024**, *17*, 850–868. [CrossRef]
38. Baghalzadeh, S.M.; Moehler, R.; Fang, Y.; Aboutorab, H.; Hijazi, A. Construction supply chain risk management. *Automat. Constr.* **2024**, *162*, 105396. [CrossRef]
39. Song, H.; Chang, R.; Cheng, H.; Liu, P.; Yan, D. The impact of manufacturing digital supply chain on supply chain disruption risks under uncertain environment-Based on dynamic capability perspective. *Adv. Eng. Inform.* **2024**, *60*, 102385. [CrossRef]
40. Yan, X.; Li, J.; Sun, Y.; Robert, S. Supply Chain Resilience Enhancement Strategies in the Context of Supply Disruptions, Demand Surges, and Time Sensitivity. *Fundam. Res.* **2023**. [CrossRef]
41. Mangla, S.; Kumar, P.; Barua, M. Risk analysis in green supply chain using fuzzy AHP approach: A case study. *Resour. Conserv. Recycl.* **2015**, *104*, 375–390. [CrossRef]
42. Agyabeng-Mensah, Y.; Ahenkorah, E.; Afum, E.; Agyemang, A.N.; Agnikpe, C.; Rogers, F. Examining the influence of internal green supply chain practices, green human resource management and supply chain environmental cooperation on firm performance. *Supply Chain. Manag.* **2020**, *25*, 585–599. [CrossRef]
43. Wang, R.; Wang, E.; Li, L.; Li, W. Evaluating the Effectiveness of the COVID-19 Emergency Outbreak Prevention and Control Based on CIA-ISM. *Int. J. Environ.* **2022**, *19*, 7146. [CrossRef] [PubMed]
44. Zhen, Y.; Dong, X.; Guo, L. Scenario inference model of urban metro system cascading failure under extreme rainfall conditions. *Reliab. Eng. Syst. Saf.* **2022**, *229*, 108888.