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Research Article

The Network Transmission Path Risk Assessment and Application of Chemical Substances in Toys

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Through the analysis of the risk transmission mechanism of chemical substances in toys, this paper identifies risk sources, transmission carriers, key nodes, and risk recipients, and draws a risk transmission path diagram. Taking the risk factors in the supply chain system as the research subject, this paper constructs a risk index system for chemical substances' limit in toys, and calculates the probability of risk and the degree of influence by the fuzzy evaluation method. Based on the Bayesian network model, this paper analyzes the causality of risk transmission effects. Through the comprehensive use of fuzzy evaluation and Bayesian network methods, a relatively complete chemical substance risk transmission path assessment system has been established using China's Guangdong toy companies as the data store to provide a feasible basis for responding to the risk control measures of toxic and hazardous chemical substances in toys.

1. Introduction

Along with the vigorous development of the global economy, people's living standards have gradually improved; as a result, toys have become an indispensable entertainment good for infants and young children. However, it has been reported that children face the hidden hazards of "toxic toys" in recent years [1], and the chemical substances contained in them cause serious harm to the healthy growth of infants and young children when come in contact or suck them. In order to protect the health and safety of children, various countries have put forward strict standards for restricting the use of toxic and hazardous chemical substances in toys (e.g., European standard EN 71 and ASTM F963 by U.S.). These standards put forward a severe test on how to control the content of chemical substances in the manufacturing process of toys. For China, as a major producer of toys, in order to better face this challenge, it is particularly important to master the risk transmission mechanism and risk assessment methods of chemical substances added to toys from raw materials, semi-finished products to finished toy goods. Based on the risk transmission mechanism of the chemical substance supply chain in toys, this paper identifies the risk factor index system, and applies the fuzzy evaluation method to quantify the probability of risk occurrence and the consequences for the sake of effectively controling the risk events caused by the content of chemical substances. Based on the Bayesian network model, the causality of risk factor transmission is calibrated so as to provide technical support for enterprises to take targeted risk prevention and control measures.

2. Research on the Risk Assessment of the Supply Chain Transmission Path

Supply chain risk has received wide-ranging attention from the academic and practice circles. Scholars at home and abroad have accumulated rich research experience on supply chain risk management (SCRM), risk identification, and risk assessment, which can effectively mitigate and avoid uncertain factors. Hudnurkar et al. (2017) mention that the common definition of supply chain risk is the degree of potential economic loss caused by the unexpected deviation of expected performance indicators or results in the supply chain caused by the triggering of interference events by enterprises in the supply chain [2]. Aven (2008) points out that the uncertain risk and loss results in the supply chain are quantifiable [3]. Harland et al. (2003) believe that with the development of globalization, supply chain networks have become more complex and risk impacts have become more dynamic [4]. Heckmann et al. (2015) describe that risk spreads along the supply chain network and exacerbates it. If a single risk is partially isolated, it will not affect the normal operation of other links in the supply chain [5]. Swierczek (2018) indicates that a variety of risk factors caused by emergencies spread in the supply chain in a forward or reverse manner [6]. These views reflect that supply chain risks are quantifiable, additive, dynamic, and directional. Compared with foreign research, there are many research results on the risk transmission mechanism and modeling analysis of the supply chain in China. Shi (2006) discusses that risk transmission requires four elements, risk source, transmission carrier, transmission node, and risk receiver [7]. Cheng and Liu (2009) [8] discuss the accumulation and release process of risk flow, the path selection, and the orderly path transmission mechanism of transmission direction. The dynamic diffusion of risk transmission is directly related to the relevance and anti-risk ability of enterprises. Zhang (2011) refines the risk transmission process of supply chain and added the dynamic elements of trigger, transmission valve, and transmission path [9]. Wan et al. (2011) [10] state that risk can be blocked or weakened by internally adjusting the node enterprises. However, when internal adjustment cannot digest the risk, the risk will spread to the upstream- and downstream-related enterprises, forming a risk accumulation and leading to a vicious circle.

In order to effectively control and reduce the risk, many researchers have developed different risk assessment methods of supply chain transmission. In recent years, domestic and foreign research on supply chain transmission risk assessment focuses more on finance and food safety. Wang et al. (2021) use the epidemic model to study the mechanism and evolution of the complex supply chain network risk transmission, and gain important management enlightenment [11]. Hernadewita and Saleh (2020) conducted a systematic analysis of 35 construction supply chain risk identification and assessment frameworks, and found that the combination of supply chain operation reference model (SCOR) and failure mode and effect analysis (FMEA) is an effective method to identify and evaluate construction supply chain risk [12]. Handayani and Prihatiningsih (2019) take small and medium-sized enterprises that produce fish balls as the research subject, identify the production risk factors based on the traceability system, and use the gray theory method to evaluate the impact of hazardous substances in halal food [13]. Zhang et al. (2018) used structural equation modeling to explore the transmission of supplier's disruption risk along the supply network in Chinese automotive-related companies, and revealed that the disruption risk affects its manufacturers, who conduct direct business trades with it [14]. Guritno and Khuriyati (2018) conducted in-depth interviews with 19 subjects at different levels in the fresh vegetable supply chain to determine the internal and external risks, and evaluated the risk management ability of each level using the expected loss ranking matrix; they analyzed the risk transfer to consumers, and farmers and traders reduced the expected loss of risk [15]. Lei and Liu (2017) use game theory to analyze the transmission mechanism of moral hazard in the supply chain of agricultural products, and find that risk entities, especially responsible entities with high correlation, can prevent and control risks to the greatest extent possible to prevent risks from occurring [16]. Liu (2015) applies the method of system dynamics to establish a risk transmission model for the vegetable supply chain in Baoding, identifies the risk factors in the system, and proposes that the risk transmission should be suppressed from quality, inventory, purchase, price, and information transmission [17]. Wang (2015) analyzes the internal and external influencing factors of the quality risk of Chinese pharmaceutical manufacturers, constructs a quality risk transmission causality diagram, analyzes the transmission influence of risk factors through system dynamics simulation, and concludes that blocking the transmission of risk transmission paths is the most significant prevention and control effect [18]. Zhang (2012) [19] used the expert scoring method and entropy method to quantitatively analyze the correlation degree and the risk threshold of supply chain node enterprises in the automobile manufacturing industry. The risk transfer coefficient is introduced to construct a selective mechanism model of supply chain risk transfer, and it is found that the correlation degree of node enterprises is positively correlated with the amount of risk transfer.

From all of the aforementioned studies, although different risk assessment methods have been applied in the fields of manufacturing, food, and medicine, the research on the identification or assessment of the transmission risk of hazardous chemical substances in toys is almost blank. At the same time, the risk transmission analysis lacks systematic risk identification, transmission effect, and comprehensive quantitative analysis of influence degree. This paper combines the Bayesian network and the fuzzy judgment analysis method to improve the transmission effect evaluation system of the risk path.

3. The Mechanism of Risk Transmission Path of Chemical Substances in Toys

3.1. Overview of the Risk Transmission Path of Chemical Substances in Toys. With reference to the concepts of corporate risk transmission in the supply chain [20] and food quality risk transmission [21], the risk transmission of chemical substances in toys refers to that in the whole supply chain system network of raw materials production, processing and manufacturing, quality inspection, storage, and transportation and distribution, the content of toxic and harmful chemicals in products exceeds the standard due to the influence of uncertain risk factors, and the transmission effect is produced along the chain network structure in production-related enterprises. The risk assessment of the chemical substances' transmission path in toys is the measurement and analysis of the uncertainty of the factors influencing the content of chemical substances in the toy supply chain to determine the possibility of the occurrence of risk factors and the degree of risk hazard, and to evaluate the risks of stakeholders in the supply chain influences.

3.2. Risk Transmission Elements of Chemical Substances in Toys

3.2.1. Risk Sources. As the origin of risk events, risk sources are a set of internal and external uncertain risk factors. The effective identification of risk sources is the first step to prevent and control the internal and external transmission of risks. The reason for the excessive content of trigger chemicals in toy products comes from the production of raw materials, processing and manufacturing of semi-finished products/finished products, and packaging and transportation. From the perspective of production and manufacturing, it involves demand design risks and manufacturing risks. The purpose of adding hazardous chemicals to toys is to change certain characteristics of the product (for example, hexavalent chromium in metal toys can improve the corrosion resistance of the product) in order to meet the performance requirements of product design, resulting in the addition of chemical substances that do not meet the standard requirements. In addition to design risks, a series of problems in the manufacturing process, such as equipment failure, backward process technology, and even manual operation errors and environmental pollution (such as polycyclic aromatic hydrocarbon chemicals in toys that are susceptible to air pollution), can increase the possibility of excessive content. From the perspective of inspection and supervision, inspection technology and equipment accuracy are the prerequisites for management and control, and effective inspection methods can reduce or prevent the business risk of purchasing or producing substandard raw and auxiliary materials. Because toys have industry standards, national standards, and national export standards, the inconsistency or lack of standard standards leads to testing difficulties. Therefore, system management has also become a necessary measure and means to control risks. From the perspective of transportation and storage, the storage, packaging, and transportation of chemical materials in toys triggers problems such as chemical pollution and causes changes in substance content.

3.2.2. Transmission Carrier. In the supply chain, risks need to be transmitted dynamically by means of carrying media such as material, technology, manpower, capital, and information. Among them, the material carrier includes raw and auxiliary materials and machinery and equipment required for toy production. The technology carrier includes R&D capabilities and production processes. R&D capabilities determine whether there are new substitute substances or processes that can be optimized to meet content requirements and achieve the characteristics of original chemical substances. The human carrier is mainly based on purchasers, inspectors, producers, technicians, and managers, and the ability to control risks among the subjects. The information carrier plays a decisive role in promoting the standardization of stakeholders. Effective information flow transmission in business can quickly respond to risk control decisions. The financial carrier is the driving force for the sustainable development of the enterprise, and the R&D and the introduction of precision equipment and instruments require a large amount of financial support.

3.2.3. Key Nodes. Key nodes refer to single or multiple risk gathering points from internal processes and external business. The node can derive, amplify, or block the harm brought by emergency events in the spatial dimension, and can transform the risk from static node to dynamic “critical point” that diffuses to another node. According to the on-the-spot investigation of toy manufacturing enterprises, through summarizing the internal processes of different toy productions (plastic toys as shown in Figure 1 and metal toys as shown in Figure 2), it can be seen that the key internal nodes of chemical content risk in products are mainly spray/paint, pad printing, and electroplating. It is reported that the content standard of chemical substances in paint raw materials is the key point of prevention and control, and the problems of process dosage, sticky pollution, and qualified sampling inspection determine the important links of reaching the standard of chemical substances in finished products. The key points of external business mainly focus on three business links, i.e., raw and auxiliary material suppliers, product manufacturers, and quality inspection institutions.

3.2.4. Risk Recipient. The recipient of the risk can also be the sender of the risk, with the characteristics of risk retention, absorption and digestion, continued transmission, and resistance [22]. The main bodies of risk recipients are chemical material suppliers, toy processing manufacturers, and quality inspection supervisors, and ultimately circulate to consumer risk recipients. If the risk recipient takes effective early warning and control measures, the risk will be digested and blocked at this node. Otherwise, it will continue to be passed on to other key links in a way of buffering degradation. At this time, the role of the receiver becomes a risk sender.

3.2.5. Transmission Path. As the name implies, transmission path is the route that risks spread to the terminal in an orderly direction. The transmission direction can be divided into chain-type forward or reverse, central radiation, network concentration, or interactive network transmission [23]. According to the analysis of the inventory status of chemical substances, the raw and auxiliary materials, semi-finished products, and finished products of toys adopt three transmission modes, chain forward, radiation, or centralized. The chain-type forward transmission path uses a unidirectional flow from upstream to downstream in the supply chain, i.e., raw and auxiliary material procurement

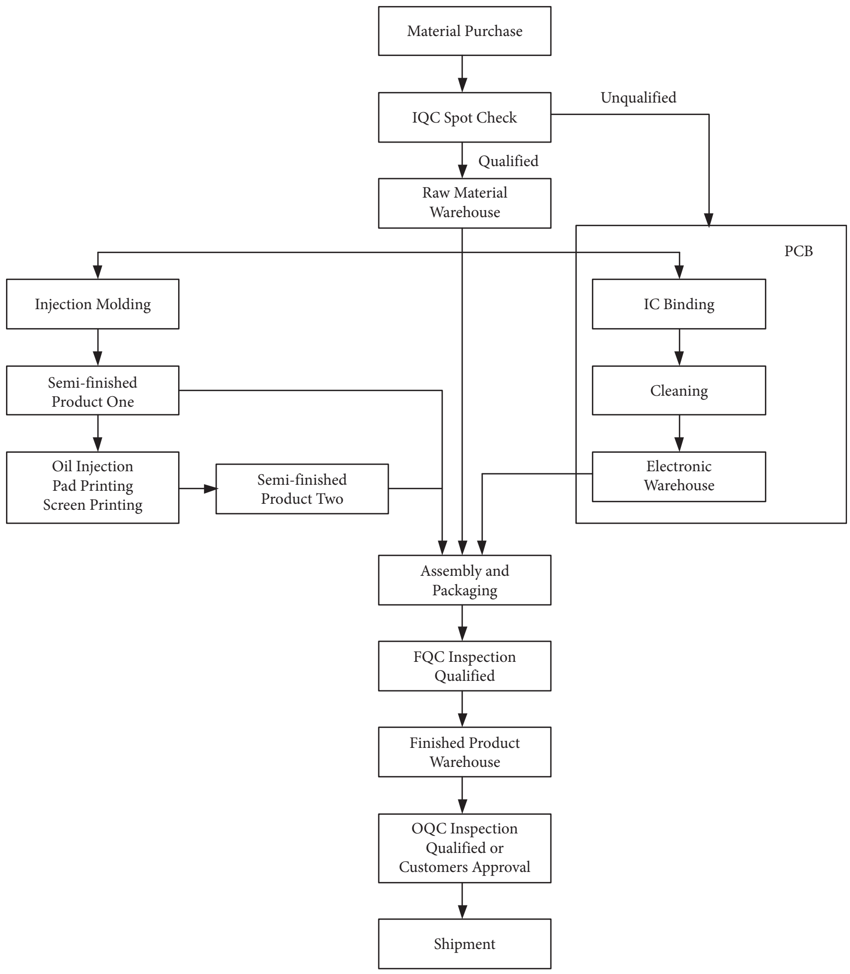

Figure 1: Production process of plastic toys.

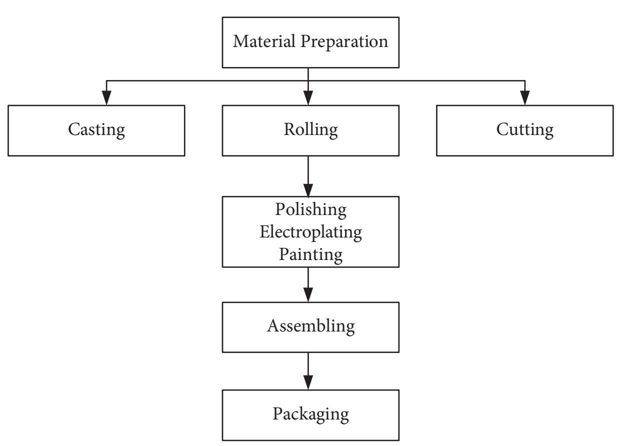

Figure 2: Production process of metal toys.

⟶ semi-finished product processing ⟶ finished product manufacturing ⟶packaging, storage, and transportation, and finally circulation to consumers. The radial transmission path transmits risks from the upstream of the supply chain to the same level or downstream levels. The risk of multiple enterprises in a centralized transmission path is all to the same enterprise. The next-level network node is enterprise transfers, and it gradually transfers to the risk recipient, namely the consumer.

Based on the research of the risk transmission mechanism of chemical substances in toys, the process of chemical substance transmission path is the process that the risk of excessive chemical content of products is transmitted to similar enterprises or downstream risk-accepting enterprises along the chain positive or network divergent mode in the toy supply chain system network. The excessive content of toxic and harmful chemical substances directly or indirectly affects the related enterprises such as raw materials, semi-finished products, and finished products. As a risk source, the excessive content relies on various risk transmission carriers such as production and processing, transportation, and products. Through the risk accumulation or coupling of related businesses, the risk will spread to the downstream key node enterprises. The risk sender is also the risk receiver in the supply chain system. Each node enterprise is a risk subsystem. The change of risk flow is related to the risk early warning, prevention and control mechanism, and the adaptive regulation mechanism of the risk subsystem. Risk receivers with strong prevention and control ability can reduce or block the risk by taking effective measures. From this, we can draw the risk transmission path map of the supply chain of chemicals in toys, which is composed of four levels (as shown in Figure 3).

4. Risk Assessment Method of Chemical Substance Transmission Path in Toys

Based on the study of chemical substance transmission mechanism in toys, it is found that the influence of risk sources on parameters in various key links is uncertain or fuzzy. The Bayesian network can solve the uncertainty of related links by means of probability reasoning. Combined with the risk transmission path map, the Bayesian network, also known as the directed acyclic graph model, is constructed to identify the risk index system. The prior probability and conditional probability of the risk event factor set are evaluated by expert experience, and then the posterior probability of other links along the directed edge is calculated. According to the obtained joint probability propagation network of risk factors, the causal relationship among the key nodes in the risk transmission path is explained.

4.1. Fuzzy Evaluation of Risk Probability and Influence Consequence

4.1.1. Establish the Risk Index System (as Shown in Table 1). Chemical substances in toys take supply and manufacturing enterprises as the key nodes. According to the risk sources identified by the transmission path, a set of risk factors $R = \{R_i | i = 1, 2 \ldots, 5\}$ = {procurement risk, production risk, R&D risk, quality inspection risk, and management risk} are established, in which the risk subset is $R_t = \{R_{it} | t = 1, 2, \ldots n\}$. Table 1.

4.1.2. Determine the Comment Set and Weight. Experts judge the probability and degree of impact of risks based on the actual situation of the enterprise, and assign values using the center of gravity method. Occurrence rating $I = \left\{I_j | j = 1, 2, 3, 4\right\}$ = {occur rarely, occur occasionally, occur frequently, and occur inevitably} = {0.1, 0.3, 0.6, 1}; the impact degree comment set and the assignment situation are shown in Table 2.

In order to reduce the impact of subjective assessment, determine the first-level indicator risk factor weight set $W = \{\omega_i\}$, which satisfies $\sum_{i=1}^{5} \omega_i = 1$ and $\sum_{i=1}^{5} \omega_i \geq 0$, set up the secondary index weight set $\widetilde{W} = \{\omega_{it}\}$, and normalize the weights separately, such as $\omega_i = \omega_i' / \sum_{i=1}^{k} \omega_i'$.

4.1.3. Fuzzy Evaluation. The paper establishes the membership vector matrix $\widetilde{D} = (d_{ij})_{m\times n}$ of the risk factor set R and rating I, where d_{ij} denotes the fuzzy mapping of each risk factor R_i corresponding to I_j. In this paper, the fuzzy transformation of the risk factors in the first-level fuzzy evaluation is carried out, and $\widetilde{P} = \widetilde{W}$. $\widetilde{D} = V_{i=1}^{n} (\omega_{it} \wedge d_{ij}) = (P_s | s = 1, 2, \ldots, m)$. According to the first-level fuzzy operation principle, the fuzzy evaluation of the second-level index and the weight matrix of the first-level index are multiplied by the fuzzy matrix to obtain the fuzzy vector of the index.

$$P' = W \circ \widetilde{P} = W \circ \begin{bmatrix} P_1 \\ P \\ P_3 \\ P_4 \\ P_5 \end{bmatrix} = (P_r | r = 1, 2, \ldots, m). \qquad (1)$$

4.1.4. Comprehensive Evaluation. The weighted average principle is used to evaluate the probability of risk occurrence.

$$P = \frac{\sum_{i=1}^{m} I_j P_r}{\sum_{j=1}^{m} P_r}. \qquad (2)$$

Among them, P_r is the membership degree of risk factor R_i to the evaluation grade I_j, and I_j is the rating assignment of the evaluation set.

4.2. Build the Bayesian Network Model. Bayesian network (BN) is a directed acyclic probability graph $G = \langle R, E, \Theta \rangle$ composed of multiple nodes, in which each node represents the corresponding risk factor variable $R = \{R_i\}$, the directed edge set E represents the dependence among variables, and the parameter Θ represents the conditional probability table (CPT) among node states. Based on the Bayesian statistical theory, the Bayesian network can calculate the joint probability distribution $P(R_1, R_2, \ldots, R_n)$ of risk events caused by excessive chemical substances, which is written by chain rules

$$\begin{aligned} P(R_1, R_2, \ldots, R_n) &= P(R_1) P(R_2 | R_1) P(R_3 | R_1, R_2) \ldots \\ &\quad P(R_n | R_1, R_2, \ldots, R_{n-1}), \\ &= \prod_{i=1}^{n} P(R_i | R_1, R_2, \ldots, R_{i-1}). \end{aligned} \qquad (3)$$

Taking toy product manufacturing and purchasing as an example, a simple Bayesian network of chemical risk events is constructed, as shown in Figure 4, where nodes

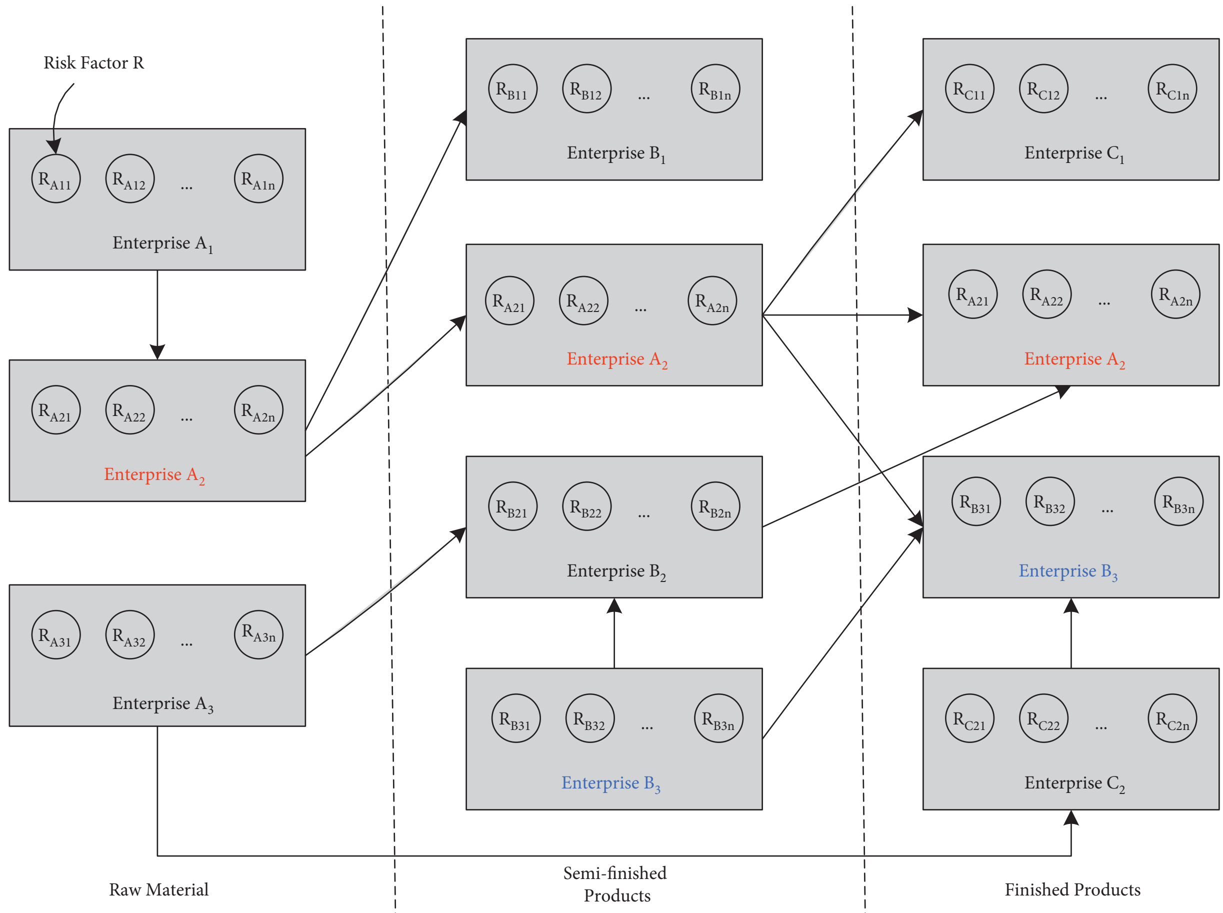

Figure 3: Risk transmission path of chemical substance supply chain in toys.

Table 1: Risk factors of toy chemical supply chain identification.

Primary indicators	Secondary indicators	Description
Procurement risk R_1	Supplier selection risk R_{11} Raw material review risk R_{12}	Supplier qualification review Storage of unqualified raw and auxiliary materials
Production risk R_2	Technology risk R_{21} Production environment risk R_{22} Staff operation risk R_{23} Packaging, storage, and transportation risk R_{24}	Risks of painting and coating links and equipment Environmental pollution triggers risk Misuse by employees Pollution or deterioration of packaging, storage, and transportation
R&D risk R_3	Product design risk R_{31} R&D capability risk R_{32}	Designer's ability to recognize standards Lack of alternative products or new technologies
Quality inspection risk R_4	Detection process risk R_{41} Testing skills risk R_{42}	Detection technology and equipment accuracy level Technical level of inspectors
Management risk R_5	Information sharing risk R_{51} Regulatory system risk R_{52} Regulatory enforcement risk R_{53} Recall product disposal risk R_{54}	Information/standard delivery delayed or inconsistent Comprehensive rationality of the management system Management execution ability level Recall product recycling and utilization

Table 2: Rating table of risk impact consequences.

Risk degree	Degree of loss caused (1000 yuan)	Evaluation (1000 yuan)
Negligible	$0 \leq I_j < 10$	5
Slight	$10 \leq I_j < 100$	55
Common	$100 \leq I_j < 500$	300
Serious	$500 \leq I_j < 1000$	750
Disastrous	$I_j \geq 1000$	1000

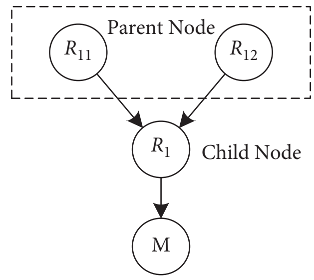

FIGURE 4: Bayesian network in procurement link of toy manufacturer M.

R_{11} and R_1 have a directed edge, and call R_{11} is the parent node of R_1. On the contrary, R_1 is the child node of R_{11}. For any child node with a parent node $Pa(R_i)$, it satisfies the joint probability distribution $P(R_1, R_2, \ldots, R_n) = \prod_{i=1}^{n} P(R_i|Pa(R_i))$; if $Pa(R_i) = \varnothing$, i.e., the probability of node R_{11} is estimated as edge distribution $P(R_{11})$. Therefore, the risk joint probability of M procurement link of finished product manufacturer $P(R_1, R_{11}, R_{12}, M) = P(R_1|R_{11}, R_{12}) \cdot P(M|R_1) \cdot P(R_{11}) \cdot P(R_{12})$. Among them.

5. Application of the Risk Assessment Method for Chemical Substance Transmission in Toys

5.1. Data Sources. This paper selects a large toy enterprise and its raw and auxiliary material suppliers in Shantou City, Guangdong Province as the research subject (as shown in Table 3). Through the open questionnaire survey and expert forum, the prior probability of risk factors is investigated by 48 professionals, and the evaluation vector is weighted by the survey results.

5.2. Fuzzy Comprehensive Evaluation

5.2.1. Determine Weight. Use the Analytic Hierarchy Process (AHP) and MATLAB software to get the weight set (as shown in Table 4) and fuzzy evaluation grade of chemical substances exceeding the standard risk $W = [0.041, 0.533, 0.093, 0.242, 0.091]$ $CR = CI/RI = 0.097/1.12 < 0.10$, pass the consistency test.

5.2.2. Probability of Occurrence and Impact Assessment. According to the fuzzy evaluation and comprehensive evaluation methods, the risk probability (P) and risk impact consequences (c) are calculated.

Through the data analysis in Table 5, it can be concluded that the risk of excessive chemical substances of domestic raw material suppliers is lower, even negligible. However, the possibility of risk caused by the finished product manufacturers in domestic and foreign trade sales markets is higher, accounting for 32.3%, but the loss caused is lower than that of raw material suppliers.

5.3. Construct a Bayesian Network Simulation Experiment. Based on the relationship between the internal and external risk factors and the supply chain production, this paper establishes the node relationship diagram between the second-level risk factors and the corresponding first-level indicators. Then, all the risk factors are gathered into the chemical risk events triggered by the enterprise. According to the prior probability and conditional probability distribution of variable parameters of each node, the posterior probability of the target node is calculated by formula (3). Then, the Bayesian network of risk of chemical substance transmission in toys is established by Netica software (as shown in Figure 5).

5.4. Risk Effect of the Chemical Substance Transmission Path in Toys. Through the demonstration data of Bayesian reasoning in Figure 5, it can be seen that when the risk occurs in the raw material node enterprise (SUPL_DOM), the associated production manufacturer enterprise (MFR_IN_DOM) will produce a transmission effect. From the Bayesian inference probability, it can be found that from the perspective of external risk, the risk has an amplified cumulative effect in the transmission process of the supply chain of the two companies. From the perspective of enterprise internal risk, due to the prevention and control measures taken by the finished product manufacturers, the risk occurrence of the node enterprises triggered by internal risk factors is inhibited or reduced. Besides, due to the constraints of the regulatory agencies or the government, the possibility of risk occurrence is further hindered.

The probability loss model $RS = PB \times C$ (RS stands for risk value) proposed by Mitchell (1995) [24] is used to measure the impact effect of risk events, which can better measure the risk level of chemical substances. Combined with the fuzzy evaluation of risk consequence C and Bayesian probability PB parameter values, the risk impact effect of the supply chain network is ranked: $RS(\text{SUPL\_DOM}) > RS(\text{MFR\_IN\_DOM})$; obviously, the risk events caused by domestic raw material supply enterprises have a greater impact. This is because the regulations or standards of toy products have not yet formed global integration, and enterprises need to meet the requirements of technical regulations and standards of different countries to enter the international sales market. Compared with foreign standards, the regulation of toy chemical safety standards in China is more relaxed. Through investigation, it is found that in order to meet the requirements of different standards, China's foreign trade enterprises have implemented the production mode of "the same standard, the same quality, and the same line," so as to avoid serious losses caused by confused production.

Table 3: Overview of toy chemical substances research enterprises.

Enterprise type	Enterprise scale	Enterprise area	Sales market
Toy products manufacturer (MID)	Large	Shantou city, Guangdong province	Integration of domestic and foreign markets
Raw material supplier (SD)	Small	Shantou city, Guangdong province	Domestic market

Table 4: Weights of risk factors in the supply chain of toy chemical substances.

Primary indicators	Weights	Secondary indicators	Weights
Procurement risk R_1	0.041	Supplier selection risk R_{11}	0.667
		Raw material review risk R_{12}	0.333
Production risk R_2	0.533	Technology risk R_{21}	0.255
		Production environment risk R_{22}	0.083
		Staff operation risk R_{23}	0.427
		Packaging, storage, and transportation risk R_{24}	0.235
R&D risk R_3	0.093	Product design risk R_{31}	0.750
		R&D capability risk R_{32}	0.250
Quality inspection risk R_4	0.242	Detection process risk R_{41}	0.200
		Testing skills risk R_{42}	0.800
Management risk R_5	0.091	Information sharing risk R_{51}	0.406
		Regulatory system risk R_{52}	0.182
		Regulatory enforcement risk R_{53}	0.351
		Recall product disposal risk R_{54}	0.061

Table 5: Results of fuzzy comprehensive evaluation.

Enterprise type	Fuzzy evaluation set of occurrence possibility	Fuzzy evaluation of occurrence possibility	Fuzzy evaluation set of influence consequence	Fuzzy evaluation grade of influence consequence
Domestic and foreign manufacturers of finished Products (MFR_INT_DOM)	(0.299, 0.398, 0.267, 0.014)	0.323	(1, 0, 0, 0)	5
Raw material supplier (SUPL_DOM)	(0.423, 0, 0, 0)	0.042	(0.77, 0.23, 0,0)	16.49

Through the comparison between the Chinese toy safety standard GB6675-2014 and the European Union toy standard EN 71–3, it is obvious that in the limit range of transferable elements in toy products, China imposes restrictions on 8 chemical elements, while the EU imposes strict restrictions on 19 chemical elements. In the future, if China formulates toy standards with international standards, increases the category of chemical elements, and reduces the threshold value of substance content, the domestic trade-oriented small and medium-sized enterprises will face a severe test. According to the Bayesian probability results in Figure 5, it is found that the raw material supply enterprises and the finished product manufacturing enterprises are in a low-level state. Among them, the most influential factor of raw material supply in the supply chain is the production link. According to the Bayesian risk probability level, the $P(SD\_R_2) > P(SD\_R_4) > P(SD\_R_1) > P(SD\_R_5) > P(SD\_R_3)$ is ranked. The factor that triggers the risk of chemical substance exceeding the standard in the finished product manufacturing enterprise is the procurement link, and the risk occurrence level is ranked as $P(MID\_R_1) > P(MID\_R_3) > P(MID\_R_4) > P(MID\_ R_2) > P(MID\_ R_5)$. Therefore, the raw material enterprises should adopt advanced production technology and substitute new technology to replace the previous production process, while the finished product manufacturing enterprises should strictly control the upstream suppliers, so as to ensure that the raw materials and auxiliary materials meet the supply standards.

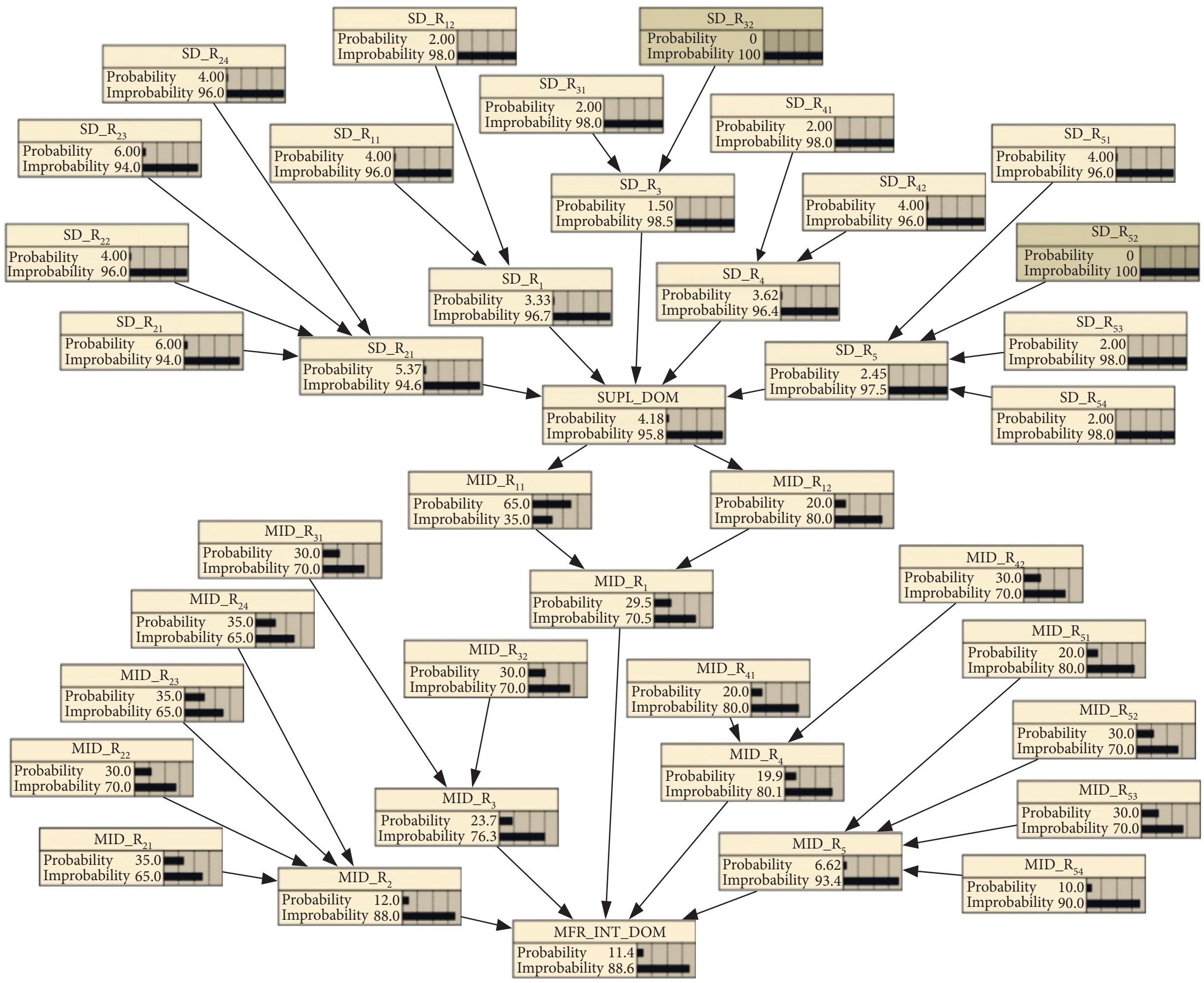

Figure 5: Bayesian network of risk of chemical substance transmission in toys.

6. Conclusion

Taking the upstream and downstream manufacturers of toy supply chain as the research subject, this paper analyzes the transmission mechanism of supply chain leading to the excessive risk of chemical substances, identifies risk factors, and establishes an index system. In this paper, fuzzy language is used to evaluate the risk probability and loss consequence, which solves the uncertainty and subjectivity of the assessment. Based on the Bayesian network probabilistic reasoning system, this paper clearly shows the conduction effect between key nodes in the supply chain. Through the comprehensive application of fuzzy evaluation and the Bayesian network evaluation method system, this paper can achieve objective evaluation, simplify the calculation complexity, and clearly infer the causal relationship, which is more scientific and reasonable.

Data Availability

The datasets generated during the current study are not publicly available due to privacy restrictions but are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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