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SHORT COMMUNICATION

Models of Formation of Reliability of Supply Chains for the Supply of Agricultural Products

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Abstract: The newest stage of economic development, which experts call the "economy of interactions", is associated with the spread of network structures and organizations, the effective operation of which requires a new quality of interaction and management. Multi-channel network supply chains are functionally and organizationally more advanced, meet the requirements of the modern market as much as possible, and allow you to form an adequate product offer in the network of relevant supply and sales channels. However, the more complex the structure of the supply chain, the higher the degree of its internal connectivity and interdependence, and the more it is exposed to uncontrollable events and, accordingly, failures or rejections. The ramifications and complexity of agricultural products supply chain increase attention to their reliability and the need to develop new methods and models for maintaining and ensuring the necessary level of reliability of the supply chain of agricultural products, especially in today's difficult geopolitical conditions.The article discusses approaches to the formation of a multi-level model of structural reliability of the supply chain. It proposes a scheme for its assessment, which quantitatively describes the state of stability of the supply chain in the event of the spread of failures and rejections. An outsourcing planning model has been studied, in which the task of forming a supply chain food turns into the task of selecting channels with the lowest costs, provided that the requirements for reliability are met. The calculations show that multi-channel (network) supply chains for agricultural products with backup channels provide increased reliability, stability, and recoverability. A series-parallel model of structural reliability has been proposed, which ensures the flexibility of the supply chain with given reliability due to the possibility of regulating the volume of supplies by channels.

Keywords: Uptime; Channel; Supply chain; Reliability; Network; Redundant element

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1. Introduction

The latest stage of economic development is directly associated with the spread of network structures and organizations, the effective activity of which requires a new quality of interaction and management, which is associated with the integration of processes and organizations into a single whole. And since the supply chain is determined by a set of interrelated (interdependent) elements, it can be considered as a network logistics system, which, in turn, consists of lower-level systems (micro-logistics systems) and at the same time is a component of meso-, macro- and mega-level logistics systems.

Domestic and foreign experts in logistics and supply chain management [1–7] note that in recent decades, the vulnerability of supply chains has been constantly growing. Global food supply chains for agricultural products face a variety of societal challenges, leaving many of them operating in a "below ideal" state, resulting in significant losses [8]. Thus, according to the Food and Agriculture Organization of the United Nations – FAO, food losses occur at all links in the supply chain and for all types of products [9].

This is because they become more complex, and the more complex the system is and the higher the degree of its internal coherence, the more it is affected by uncontrollable events. Therefore, the supply chain for agricultural products reliability management remains one of the most complex theoretical and insufficiently developed problems.

The article aims to form a multi-level model of structural reliability of the supply chain in case of propagation of failures and failures.

It should be noted that several works [10–14] are devoted to the analysis of supply chains from the point of view of their functional reliability, in which an approach to assessing the reliability of supply chains, based on the theory of reliability of technical systems, has become widespread. There were prerequisites for applying the theory of reliability of technical systems in logistics before but works on implementing reliability calculations appeared relatively recently.

Therefore, our work aims to build a multi-level model of structural reliability of the supply chain agricultural products in case of propagation of failures and rejections.

2. Materials and Methods

2.1 Multi-Channel Supply Models

The formation of a multi-channel supply agricultural products model forms a fundamentally new role of logistics, which not only provides the opportunity to differentiate the product and service offer but also creates an additional barrier to market entry, increasing the monetization of retail in digital distribution channels.

And it is the combination of logistics and service in online retail that becomes the main catalyst for the development of the modern commodity market [15].

It should be noted that in the scientific literature, among the various approaches to assessing and ensuring the reliability of supply chains [16–20], the most widespread are:

a. Process approach and SCOR model developed on its basis;
b. Creation of dynamic supply chains;
c. Assessment of the quality of logistics service based on the "perfect order" indicator.

Each of these approaches has its advantages and disadvantages, and discussions about the effectiveness of their application have not stopped in recent years.

Thus, in the SCOR model, the efficiency of the supply chain is determined based on an assessment of indicators that characterize such parameters of functioning as reliability, response speed, flexibility, costs, and efficiency of supply chain asset management [21,22]. Accordingly, the limitation of the SCOR model in assessing the reliability of the supply chain, in its opinion, is that, firstly, this model has a limited interpretation of the concept of supply chain reliability [23]. Secondly, the assessment of the efficiency of the supply chain and, in particular, its reliability is carried out by comparing the indicators achieved in the company with the indicators of the leading companies in this area of business [24]. Obviously, such a comparison does not always allow for a correct assessment of both the efficiency and reliability of the supply chain. Finally, since the model is descriptive, supply chain reengineering does not guarantee that business processes will be optimal [25] and that supply chain efficiency and reliability will be the highest.

Analysis of the problem of creating dynamic supply chains [26–29] suggests that, of course, achieving agility across the entire supply chain gives companies a global competitive advantage by reducing lead times, setting up time, using modular manufacturing, and reducing inventories. But still, the creation of a dynamic supply chain allows you to achieve, first of all, an increase in the efficiency, not reliability of the supply chain.

In the model for assessing the quality of logistics services based on the "perfect order" indicator (POF), the principle of ensuring the reliability of the supply chain is to accurately perform all operations of the full order cycle in strict accordance with the contractual terms [30], that is, to maximize the efficiency of all aspects of the delivery process, including the accuracy of order fulfillment, timeliness of delivery, absence of defects and accuracy of accompanying documentation. But the main problem is that achieving a 100% rate of perfect orders is an extremely difficult task due to a variety of factors that can affect the supply process; scientific publications describe cases of accounting from 3 to 11 transactions (or factors) that are considered when determining the level of POF [31,32].

However, multi-channel (network) supply chains are prone to more failures because the stability, security, and reliability of the state of such chains depend on the well-coordinated (ideal) operation of all elements that make up them.

Therefore, the study of multi-channel (network) supply chains requires a combination of all the above approaches and the development of integrated reliability models. In our opinion, all methods of improving the reliability of such supply chains should be considered from the point of view of the following areas:

a. Technical, based on the theory of reliability of technical systems.
b. Economic, which involves assessing the reliability of supply chains based on logistics costs.
c. Security-based risk-based business processes in supply chains.

2.2 Functional Diagram of the Multi-Channel Supply Model

The schemes of supply chain for agricultural products organization is considered in the example of ensuring the “Source” process in the classical SCOR model, which is graphically represented in Figure 1.

To solve the problem of rationing supplies, the requirement for reliability is defined:

$$P_0(t_0) = \phi(P_1, P_2, \dots, P_n) \geq P_2^* \tag{1}$$

where: $\phi(P_1, P_2, \dots, P_n)$– function defined by the functional reliability scheme (redundancy scheme);

P_2^* – the requirement of the end user for the reliability of supplies, which is stipulated by the responsible supplier or supply operator (supplier of the 1st level).

If it is impossible to fulfill the contractual terms on its own, the supplier of the 1st level (Figure 1) forms a network of 2nd level suppliers on the principles of outsourcing, which, in turn, can form networks of the 3rd, 4th and further levels on the same principles.

Failures in such a supply chain are understood as independent events consisting of a breach of contractual terms in one or more functional parameters, such as time, sequence, completeness, or volume of supply. Therefore, in such models, backup elements are introduced “in parallel” with elements, the reliability of which is questionable.

$$P_0 = \prod_{i=1}^{n} P_i = P_1 \times P_2 \times P_3 \dots \times P_n \tag{2}$$

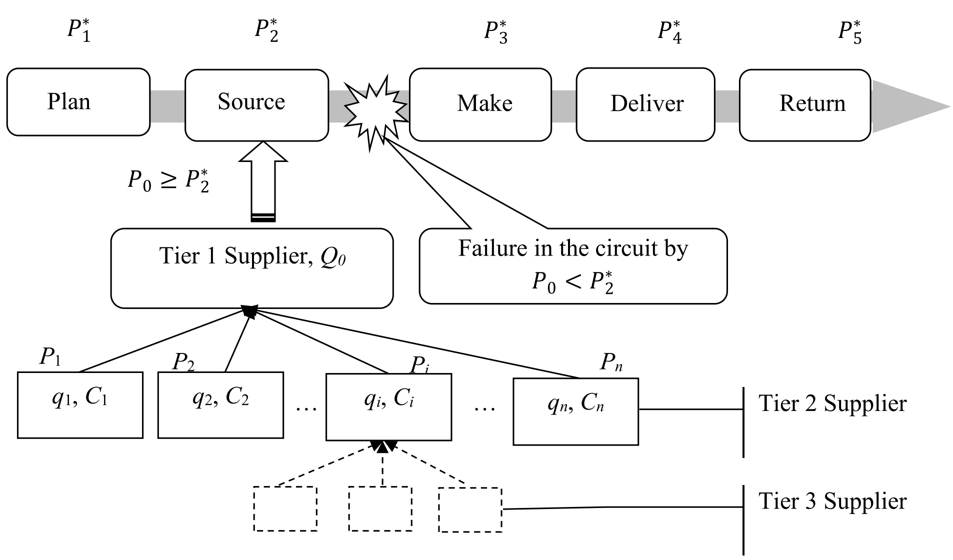


Figure1. Functional diagram of the supply chain.

Note: Q_0 – the required volume of supply for the planned time t_0;

P_i, q_i, C_i – probability of uptime, capacity, and cost of deliveries via thei-th channel, respectively.

The number of reserve elements in the system is determined separately for each case, for example, in P. According to Ballou [33], there are five of them. Also, when forming a multi-product order, it is recommended to use the WAFR formula (weighted average rating factor).

$$P_0 = \sum \omega_i \times P_i \tag{3}$$

where: w_i – weighting coefficient for the i-th nomenclature.

P_i – the probability of trouble-free formation of the i-th nomenclature of the order.

However, given the complexity and stochasticity of processes and the variety of optimization goals, when constructing a reliability model to solve specific planning problems, only a part of the overall supply chain and the associated costs can be examined.

3. Results and Discussion

3.1 Supply Planning Taking into Account the Functional Reliability of Carriers

Taking into account that the ultimate goal of logistics is to reduce the cost of logistics services and predict the probability of system failures, for transport and logistics processes, the concept of reliability implies the delivery of goods on time, its security, safety, and adequacy of accompanying documents. However, the number of tasks for optimizing logistics processes in supply chains in terms of increasing their reliability is extremely large, and their composition is diverse. Therefore, to save resources, any economic entity must carefully build a system of restrictions on the resources used and key factors influencing reliability at any level of the supply chain. Thus, the task of planning deliveries taking into account the functional reliability of carriers consists of the following steps [34]:

a. Building a functional diagram of the supply chain for agricultural products, indicating all Tier 2 carriers and their characteristics.
b. Definition of the concept of refusal and establishment of the value of the criterion for the functionality of carriers based on the requirements of the customer.
c. Drawing up a series-parallel scheme and a model for calculating structural reliability based on the requirements for the reliability of supply and the functionality of carriers.
d. Determination of the optimal supply plan that ensures a minimum of costs for compliance with the requirements for reliability.

The paper [35] presents an outsourcing model of planning, where for the customer the task of forming a supply chain turns into the task of choosing channels at the lowest cost, provided that the requirements for parameters and reliability are met. At the same time, it is noted that outsourcing to a third party can work effectively only if an external coordinator can ensure a low cost of knowledge transfer in the supply chain. Under such conditions, reliability can be determined by the formula of the simplest paralyzed circuit:

$$1 - \prod_{i=1}^{m}\left(1 - \prod_{j=1}^{n} P_j\right) \geq P_0; \quad if X_{ij} \geq 0 \tag{4}$$

where: n is the number of channels (suppliers);

m is the number of supply chains.

Such models are usually supplemented by the terms of cost limits for the operation of the system. Accordingly, the mathematical model of such a task is as follows:

$$heS(X) = \sum_{i=1}^{m}\sum_{j=1}^{n} X_{ij} \times Z_j \times C_j \tag{5}$$

under restrictions:

$\sum_{i=1}^{m}\sum_{j=1}^{n} X_{ij} \times Z_j = Q_0$; requirements for the volume of supplies

$\sum_{i=1}^{m} X_{ij} \times Z_j \leq q_j j = 1$, n; requirements for the capacity of supply chains

$1 - \prod_{i=1}^{m}\left(1 - \prod_{j=1}^{n} P_j\right) \geq P_0;\ if X_{ij} \geq 0$; supply reliability requirement

$Z_j \geq d j = 1$, n; minimum Order Quantity Requirements

where: $X_{i,j}$ – a binary variable (choice variable) that takes a value of 0 or 1;

Z_j – optimal J-th Supply Channel Plan ;

C_j – the cost of the j-th supply channel;

Q_j – the volume of the j-th supply channel;

q_j – possible volume (capacity) of deliveries via the j-th channel.

In this model, the objective function determines the most attractive minimum cost chain, in which a network of m supply chains with a series-parallel scheme of structural reliability is formed from n channels. The optimal supply plan is the result of solving a mathematical programming problem, where the reliability of the network channel is included in the optimization plan. In this case, the objective function of the system can be written as follows:

$$S(X_0) = \sum_{i=1}^{m}\sum_{j=1}^{n}\left(1 - \prod_{j=1}^{n} P_{ij}\right)X_{ij} \times Z_j \times C_j \to min \quad (6)$$

with similar constraints as in the previous formula.

3.2 An Example of Determining the Optimal Supply Plan that Minimizes the Costs of a 4-Channel Supply Chain

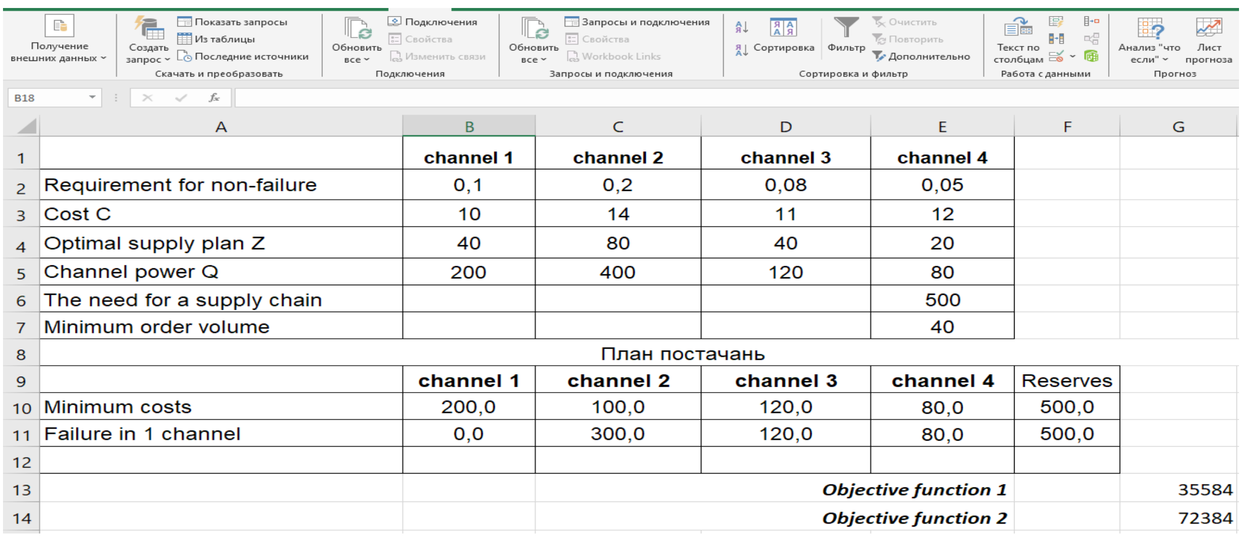
The task of determining the optimal supply plan that ensures the minimum costs of a 4-channel supply chain with a series-parallel scheme of structural reliability under the indicators and constraints provided in Table 1 can be solved using the Excel editor "Search for a solution" (Figures 2 and 3).

The results of the calculations show that with the trouble-free operation of all four supply channels, the minimum cost of supplying 500 units of goods is 35584 UAH. per month. In case of failures in the supply of the first channel, they increase to 72384 UAH. However, the necessary (defined) security of supply remains. Consequently, multi-channel supply chains with redundant channels provide increased reliability, resilience, and recoverability.

This approach allows you to solve the problem of not only ensuring the necessary reliability of supplies at minimal cost but also selecting a chain from the channels with the highest reliability. This model is one of the directions in the development of models for optimizing supply planning, considering the reliability (reliability) of the implementation of strategic plans and the definition of supply chains with high reliability.

Table 1. Characteristics of a multi-channel supply chain.

	Channel 1	Channel 2	Channel 3	Channel 4
Channel performance metrics				
Cost C, UAH units	10	14	11	12
Optimal supply plan Z, units	40	80	40	20
Channel power Q, units	200	400	120	80
Reliability of supply, %	90	80	92	95
Supply constraints				
On the volume of supply	500			
For minimum order quantity	40			
Reliability requirement	0.2			



	A	B	C	D	E	F	G
1		channel 1	channel 2	channel 3	channel 4		
2	Requirement for non-failure	0,1	0,2	0,08	0,05		
3	Cost C	10	14	11	12		
4	Optimal supply plan Z	40	80	40	20		
5	Channel power Q	200	400	120	80		
6	The need for a supply chain				500		
7	Minimum order volume				40		
8				План постачань			
9		channel 1	channel 2	channel 3	channel 4	Reserves	
10	Minimum costs	200,0	100,0	120,0	80,0	500,0	
11	Failure in 1 channel	0,0	300,0	120,0	80,0	500,0	
12							
13					*Objective function 1*		35584
14					*Objective function 2*		72384

Figure 2. Calculation of the optimal supply plan.

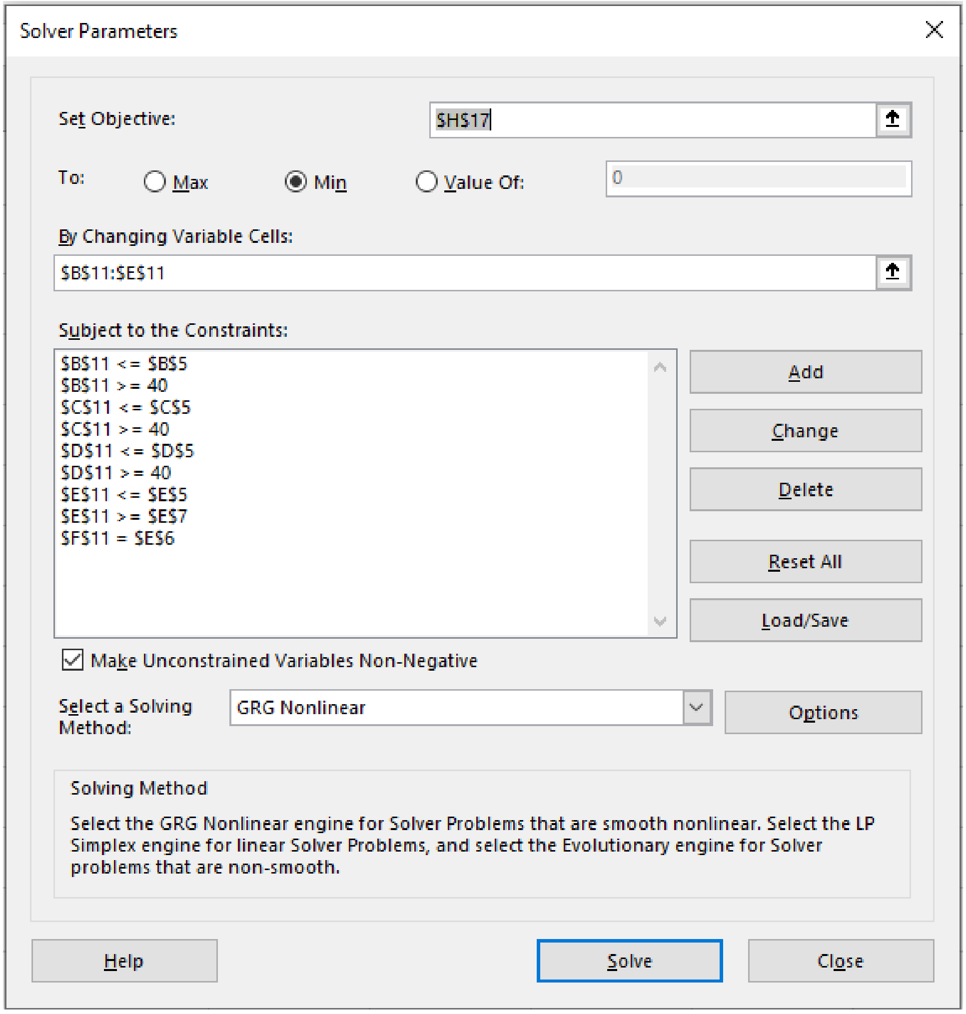


Figure 3. Solution search options.

3.3 Choosing the Most Cost-Effective Supply Chain

However, given that a supply chain for agricultural products may consist of channels with different characteristics, a network model of structural reliability will typically include channels consisting of individual suppliers and supply chains, or even entire subnets with a relatively complex structure. So Figure 4 shows that to ensure a given probability of uptime of the *supply chain* P_0, it is necessary to create a network of n channels by analyzing suppliers in the market and evaluating their potential functionality. These suppliers to ensure their probability of uptime p_1, p_2,... p_{Ns}, in turn, can build networks of levels 3, 4 and higher on the basis of the same principles.

Accordingly, for the customer, the problem of building a supply chain turns into the problem of choosing the most cost-effective channel that meets the requirements for functional parameters (such as fail-safe performance determined using the formula for a series-parallel supply chain structure):

$$P_0 = 1 - \prod_{i=1}^{m}\left(1 - \prod_{j=1}^{n} p_j\right)_i, \quad m \le n, \quad if\, x_{ij} not \quad 0 \tag{7}$$

where: n – number of suppliers;

m – number of supply chains (channels);

$x_{i,j}$ – A binary variable (choice variable) that takes a value of 1 if the capacity of the *j-supplier* included in the *i-th* supply channel allows to meet the demand, 0 if it does not allow $\sum_{o=1}^{n} q_j x_{ij} \ge Q_0 \sum_{o=1}^{n} q_j x_{ij} \le Q_0$. Here, the binary variable serves to form m circuits of n channels.

Considering the reliability model of a complex network, in this case a series-parallel structural supply network (see Figure 5), we can note that in this case, according to $n = m$, the structural reliability model of the supply network consists of n parallel connected channels with power $q_j \ge Q_0$.

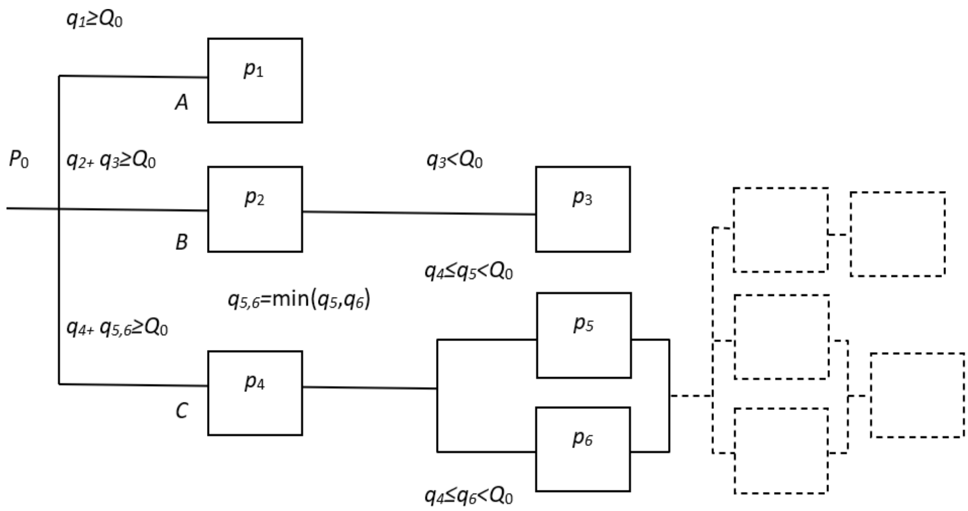


Figure 4. Multilevel model of structural reliability of the supply network.

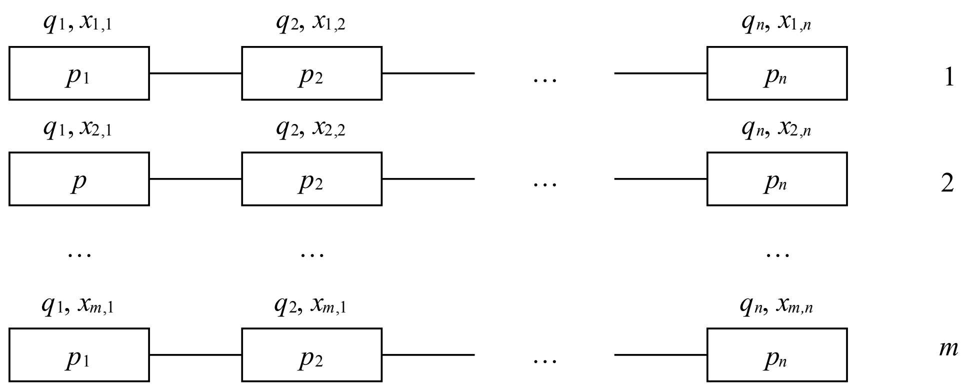


Figure 5. Series-parallel model of structural reliability of the supply network.

This makes it possible to use the logical-probabilistic method of analysis to form multi-level complexly structured models of the supply network. To do this, we introduce variables representing the value of deliveries of goods from the j-th supplier included in the i-th supply channel. Then the optimal supply plan is determined as a result of solving the problem of mathematical programming with the objective function:

$$S_0 = \sum_{i=1}^{m} \sum_{j=1}^{n} c_j z_{i,j} x_{i,j} + \sum_{j=1}^{n} R_j x_{i,j} \to min \tag{8}$$

subject to restrictions:

$$1 - \prod_{i=1}^{m} (1 - \prod_{j=1}^{n} p_j)_i \geq P_0 \, if x_{i,j} not 0;$$

$$\sum_{i=1}^{m} \sum_{j=1}^{n} z_{i,j} x_{i,j} = Q_0;$$

$$0 \leq \sum_{i=1}^{m} x_{i,j} \leq 1, j = 1, \ldots, n;$$

$$\sum_{i=1}^{m} z_{i,j} x_{i,j} \leq q_j, j = 1, \ldots, n;$$

$$\sum_{i=1}^{m} z_{i,j} \geq d, j = 1, \ldots, n;$$

$$\sum_{j=1}^{n} q_j x_{i,j} \geq Q_0 if x_{i,j} not 0, i = 1, \ldots, m;$$

$$z_{i,j} \geq 0, i = 1, \ldots, m, j = 1, \ldots, n;$$

$$z_{i,j} \in R, i = 1, \ldots, m, j = 1, \ldots, n;$$

$$x_{i\,j} \in \{0,1\}, i = 1, \ldots, m, j = 1, \ldots, n.$$

The objective function (8) is the sum of variable and fixed costs in a given supply management system. In the system of constraints, the first constraint is the requirement for the reliability of a supply chain consisting of series-parallel elements. The condition means: if $x_{i,j}$ not 0, then the value of p_j. Otherwise, it is not included in the product, that is, only the probabilities of the channels included in the chain are multiplied.

The second constraint is the supply volume requirement: a standard limit on the total supply 0 across all network channels.

The third restriction is that the condition of including the supplier in one channel (one chain) means that the supplier can enter only one channel or not enter any of them (extra channel).

The fourth restriction is the restriction on the supply of suppliers q_i.

The fifth restriction is the minimum order *d*, which takes into account the costs associated with the conclusion of the supply contract, i.e., it is an economic condition of the contract.

The sixth restriction is the condition for the formation of a supply channel: each channel must provide a supply of at least Q_0, and only the volumes for suppliers included in the channel are summed up, that is if $x_{i,j}$ not 0.

Finally, the seventh, eighth, and ninth constraints indicate that variables $z_{i,j}$ are non-negative real numbers, but $x_{i,j}$ are Boolean variables.

The proposed model provides flexibility of the supply chain with a given reliability due to the possibility of regulating the volume of supplies through channels. At the same time, several problems arise when solving such a problem. Firstly, it is the complexity of calculating the probability of uptime of the supply network P_0, which requires the use of the logical-probabilistic method, i.e., the description of all operational and inoperable states of the supply network using logic algebra functions [36], and secondly, the complexity lies in the large number of possible functional states of the system, especially in multi-level supply networks. Overcoming these problems is possible by dividing a complex circuit into simpler ones and developing their topology under conditions of minimizing costs and increasing the level of reliability to a given value. In this case, there will be a decomposition of the complex model for ensuring the reliability of the supply chain into several submodels for ensuring the reliability of individual business processes.

4. Conclusions

The study of the problem of forming a multi-level model of structural reliability of the supply chain has shown that the number of tasks for optimizing logistics processes to increase its reliability is extremely large, and their composition is diverse.

According to the outsourcing model, the formation of a supply chain for agricultural products becomes the task of selecting channels at the lowest cost, provided that the requirements for reliability are met. The calculations of the supply plan show that multi-channel supply chains with backup channels provide increased reliability, stability, and recoverability.

The series-parallel model of structural reliability proposed in the paper makes it possible to use the logical-probabilistic method of analysis for the formation of multi-level complex-structured models of the supply network and ensures the flexibility and reliability of the supply chain due to the possibility of regulating the volume of supplies through channels. This method, in comparison with other methods, provides a more complete and accurate analysis of the system, since it allows you to consider both deterministic and random factors that affect the functioning of a multi-level supply network

The approaches considered in the publication contribute to both increasing the reliability of supply chains in general and their business processes; their application in practice will reduce the logistics costs of agricultural enterprises and increase the efficiency of individual business processes.

Author Contributions

Conceptualization, formal analysis, and writing – Zagurskiy O.; original draft preparation methodology and project administration – Savchenko L.; methodology – Duczmal W.; data curation and visualization, funding acquisition – Ohiienko M.

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Data Availability

Not available.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Haidong, G., Shengyu, W., Yu, Z., 2021. Supply

interruption supply chain network model with uncertain demand: An application of chance-constrained programming with fuzzy parameters. Discrete Dynamics in Nature and Society. 2021, 1-8.

[2] Kottala, S.Y., Sahu, A.K., 2023. Evaluating ergonomics and financial distress in manufacturing organization behavior: Resiliency framework from operations and strategic management. The Learning Organization. 31(5), 765-788. DOI: https://doi.org/10.1108/TLO-03-2023-004

[3] López-Castro, L.F., Solano-Charris, E.L., 2021. Integrating resilience and sustainability criteria in the supply chain network design. A systematic literature review. Sustainability. 13(19), 10925.

[4] Rha, J.S., 2020. Trends of research on supply chain resilience: A systematic review using network analysis. Sustainability, MDPI. 12(11), 1–27.

[5] Zagurskiy, O., Pivtorak, M., Bondariev, S., et al. (editors), 2023. Methods of reliability management in supply chain. Proceedings of 22st International Scientific Conference Engineering for Rural Development; May 24 – May 26, 2023; Jelgava, LATVIA. p. 76–84.

[6] Ali, I., Arslan, A., Chowdhury, M., et al., 2022. Reimagining global food value chains through effective resilience to COVID-19 shocks and similar future events: A dynamic capability perspective. Journal of Business Research. 141, 1-12.

[7] Mishra, R., Singh, R.K., 2023. A systematic literature review on supply chain resilience in SMEs: Learnings from COVID-19 pandemic. International Journal of Quality & Reliability Management. 40(5), 172–1202.

[8] Zagurskiy, O.M., Zhurakovska, T.S., 2021. Food supply transport and logistics system organizations. Machinery & Energetics. Journal of Rural Production Research. 12(4), 53-59.

[9] FAO., 2023. Annual Report 2023. Available from: https://www.fao.org/fileadmin/user_upload/Corporate_Environmental_Responsibility/docs/cc9133en.pdf (cited 15 July 2024).

[10] Ahmed, H.F., Hosseinian-Far, A., Khandan, R., et al., 2022. Knowledge sharing in the supply chain networks: A perspective of supply chain complexity drivers. Logistics. 6(3), 66. DOI: https://doi.org/10.3390/logistics6030066

[11] Dolgui, A., Ivanov, D., 2020. Exploring supply chain structural dynamics: New disruptive technologies and disruption risks. International Journal of Production Economics. 229, 107886.

[12] Kumar, D., Soni, G., Kazancoglu, Y., et al., 2023. On the nature of supply chain reliability: Models, solution approaches and agenda for future research. International Journal of Quality & Reliability Management. 11(1), 133-139. DOI: https://doi.org/10.1108/IJQRM-08-2022-0256

[13] Zhang, M., Chen, J., Chang, S-H., 2020. An adaptive simulation analysis of reliability model for the system of supply chain based on partial differential equations, Alexandria Engineering Journal. 59(4), 2401-2407.

[14] Raj, A., Mukherjee, A.A., Srivastava, S.K., et al., 2022. Supply chain management during and post-COVID-19 pandemic: Mitigation strategies and practical lessons learned. J Bus Res. 142, 1125–1139. DOI: https://doi.org/10.1016/j.jbusres.2022.01.037

[15] Zagurskiy, O., 2014. Systematic and evolutionary approach to market research. Economic Annals-XXI. 11-12, 8-11.

[16] Artsiomchyk, Y., Zhivitskaya, H., (editors), 2016. Supply chain reliability analysis and performance measurements. 2016 International Conference on Information and Digital Technologies (IDT); July 5 – July 7, 2016; Rzeszow, Poland. p. 5-10. DOI: https://doi.org/10.1109/DT.2016.7557142

[17] Emrouznejad, A., Abbasi, S., Sıcakyüz, Ç., 2023. Supply chain risk management: A content analysis-based review of existing and emerging topics. Supply Chain Analytics. 3, 10003.

[18] Friederich, J., Lazarova-Molnar, S., 2024. Reliability assessment of manufacturing systems: A comprehensive overview, challenges and opportunities. Journal of Manufacturing Systems. 72, 38-58.

[19] Shishodia, A., Sharma, R., Rajesh, R., et al., 2023. Supply chain resilience: A review, conceptual framework and future research. The International Journal of Logistics Management. 34(4), 879-908. DOI: https://doi.org/10.1108/IJLM-03-2021-0169

[20] Zhang, J., Li, H., Golizadeh, H., et al., 2020. Reliability evaluation index for the integrated supply chain utilising BIM and lean approaches. Engineering, Construction and Architectural Management. 27(5), 997-1038. DOI: https://doi.org/10.1108/ECAM-12-2018-0542

[21] Lima-Junior, F.R., Carpinetti, L.C.R., 2019. Predicting supply chain performance based on SCOR® metrics and multilayer perceptron neural networks. International Journal of Production Economics. 212, 19-38.

[22] Özkanlısoy, Ö., Bulutlar, F., 2023. Measuring supply chain performance as scor v13.0-based in disruptive technology era: Scale development and validation. Logistics. 7, 65. DOI: https://doi.org/10.3390/logistics7030065

[23] Van Engelenhoven, T., Kassahun, A., Tekinerdogan, B., 2023. Systematic analysis of the supply chain operations reference model for supporting circular economy. Circ.Econ.Sust. 3, 811-834. DOI: https://doi.org/10.1007/s43615-022-00221-6

[24] Jamehshooran, B.G., Shaharoun, M.A., Haron, H., 2015. Assessing supply chain performance through applying the SCOR model. International Journal of Supply Chain Management. 4, 1-11.

[25] Koot, M., Mes, M.R.K., Iacob, M.E., 2021. A systematic literature review of supply chain decision making supported by the Internet of Things and Big Data Analytics. Computers & Industrial Engineering. 154, 107076.

[26] Kappelman, A.C., Sinha, A.K., 2021. Optimal control in dynamic food supply chains using big data. Computers & Operations Research. 126, 105117.

[27] Rolf, B., Klementzki, V., Lang, S., et al., 2023. A scoping review on dynamic networks in supply chains. IFAC-PapersOnLine. 56(2), 203-214.

[28] Sarimveis, H., Patrinos, P., Tarantilis, C., et al., 2008. Dynamic modeling and control of supply chain systems: A review. Computers & Operations Research. 35(11), 3530-3561. DOI: https://doi.org/10.1016/j.cor.2007.01.017

[29] Davizon, Y.A., Amillano-Cisneros, J.M., Leyva-Morales, J.B., et al., 2023. Mathematical modeling of dynamic supply chains subject to demand fluctuations. Engineering, Technology & Applied Science Research. 13(6), 12360-12365.

[30] Najmi, A., Gholamian, M., Makui, A., 2013. Supply chain performance models: A literature review on approaches, techniques, and criteria. Journal of Operations and Supply Chain Management. 6(2), 94-113. DOI: https://doi.org/10.12660/joscmv6n2p94-113

[31] Christopher, M., 2011. Logistics And Supply Chain Management, 4th ed. Financial Times/Prentice Hall. Dorchester: Dorset. pp. 288.

[32] Lambert, D.M., García-Dastugue, S.J., Croxton, K.L., 2005. An evaluation of process-oriented supply chain management frameworks. Journal of Business Logistics. 26(1), 25-51.

[33] Ballou, R.H., 2004. Business Logistics/Supply Chain Management: Planning, Organizing and Controlling the Supply chain, 5th ed., Pearson/Prentice Hall Inc.: New Jersey. pp. 789.

[34] Ghorbani, M., Ramezanian, R., 2020. Integration of carrier selection and supplier selection problem in humanitarian logistics. Computers & Industrial Engineering. 144, 106473.

[35] Lu, Q., Meng, F., Goh, M., 2014. Choice of supply chain governance: Self-managing or outsourcing?, International Journal of Production Economics. 154, 32–38.

[36] Zagurskiy, O., Savchenko, L, Ohiienko, A., et al., (editors), Methodology for the Formation of the Company's Logistics Service System. Proceedings of 23st International Scientific Conference Engineering for Rural Development; May 22 – May 24, 2024; Jelgava, LATVIA. p. 105-112. https://www.tf.lbtu.lv/conference/proceedings2024/