Scientific article
UDC 330.47
DOI: https://doi.org/10.57809/2025.4.4.15.7

PROFIT-RISK OPTIMIZATION TASK FOR A HYBRID WAREHOUSE CONFIGURATION

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Abstract. Object of study: hybrid warehouse architecture for e-commerce, integrating a physical warehouse and a virtual dropshipping channel. Methods: comparative analysis based on financial, operational, and risk-oriented indicators, supported by a mathematical framework incorporating supplier reliability. Results: the study reveals fundamental trade-offs between liquidity, risk, delivery speed, and costs. The hybrid model releases up to 40% of working capital but reduces profit by 25.3% at a supplier reliability of β = 0.95. Risk adjustment decreases expected profit by 11.25% compared to the nominal calculation. Conclusions: a verbal optimization problem is formulated to maximize profit under risk and delivery time constraints, providing a structured approach for managing hybrid systems instead of intuitive selection.

Keywords: hybrid warehouse architecture, inventory management, e-commerce, dropshipping, supplier reliability, risk management, profit optimization, supply chain, logistics, working capital, order fulfillment, multi-channel retail

Citation: Ermochenko S. Profit-risk optimization task for a hybrid warehouse configuration. Technoeconomics. 2025. 4. 4 (15). 90–101. DOI: https://doi.org/10.57809/2025.4.4.15.7

Научная статья
УДК 330.47
DOI: https://doi.org/10.57809/2025.4.4.15.7

ЗАДАЧА ОПТИМИЗАЦИИ ПРИБЫЛИ И РИСКА ДЛЯ ГИБРИДНОЙ СКЛАДСКОЙ КОНФИГУРАЦИИ

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Аннотация. Объект исследования — гибридная складская архитектура интернет-магазина, сочетающая физический склад и виртуальный канал по схеме дропшиппинга. Метод исследования включает сравнительный анализ архитектур на основе системы финансовых, операционных и риск-ориентированных показателей, а также разработку математического аппарата, учитывающего надежность поставщика. Результаты демонстрируют системные компромиссы между ликвидностью, риском, скоростью доставки и затратами: гибридная модель высвобождает оборотный капитал до 40%, но снижает прибыль на 25,3% при надежности поставщика β = 0,95. Учет риска снижает ожидаемую прибыль на 11,25% по сравнению с номинальным расчетом. Выводы: предложена вербальная постановка оптимизационной задачи максимизации прибыли при ограничениях на риск и время доставки, что позволяет перейти от интуитивного выбора к количественному управлению гибридной системой.

Ключевые слова: гибридная складская архитектура, управление запасами, электронная коммерция, дропшиппинг, надежность поставщика, управление рисками, оптимизация прибыли, цепь поставок, логистика, оборотный капитал, выполнение заказов, многоканальная торговля

Для цитирования: Ермоченко С. Задача оптимизации прибыли и риска для гибридной складской конфигурации // Техноэкономика. 2025. Т. 4, № 4 (15). С. 90–101. DOI: https://doi.org/10.57809/2025.4.4.15.7

Introduction

In the modern world, the impact of digitalization on all sectors of the economy, including retail trade, is undeniable. The development of e-commerce has become not only a new sales channel but also a catalyst for significant changes in supply chain and logistics management. As Martin Christopher notes in his book "Logistics & Supply Chain Management," competition between individual companies is being replaced by competition between supply chains (Christopher, 2016). This trend exacerbates the problem of working capital management, as the need to maintain a high level of product availability for rapid customer delivery inevitably leads to the problem of "frozen" resources in inventory.

However, classical inventory management models, which underpin many systems, demonstrate low efficiency in the context of hybrid business models, whose architecture combines the operation of owned physical warehouses and online sales. Traditional push and pull strategies (Gou et al., 2016), prove insufficiently flexible in coordinating supply and demand in such models. This is because these strategies were developed for a context assuming unified control over logistics flows and full transparency of inventory information. In a hybrid environment, where some operations are outsourced to external suppliers (virtual warehouse), a fundamentally new risk architecture and cost structure emerge. The key challenge becomes not merely optimizing inventory levels, but optimally allocating products and demand between fundamentally different fulfillment channels, each characterized by a unique balance between operational costs, lead time, risks of default, and impact on cash flows.

Existing scientific works primarily focus either on traditional schemes with owned warehouses (Li and Mizuno, 2022; Soleimani et al., 2020; Xu et al., 2021; Babkina, 2024) or on models entirely based on outsourced capacities (Vandeput, 2020; Hasan et al., 2024). In the first case, researchers, following the classical paradigm, elaborate in detail on optimizing inventory management parameters (such as reorder point and safety stock levels) under stable or stochastic demand but ignore the possibility of dynamically redirecting orders to external capacities to reduce capital expenditures. In the second case, studying models like dropshipping, the emphasis shifts to supplier coordination and minimizing inventory investments; however, the strategic value of a combined approach, which allows for flexible distribution of product flows between channels based on their operational characteristics, is not considered. At the same time, combined approaches integrating both logics are not sufficiently studied. A review of contemporary research in inventory management for multi-channel retail confirms that, despite growing interest in the topic, research dedicated to the integration of physical and virtual warehouse accounting models remains limited, particularly in terms of determining optimal inventory allocation and risk-sharing mechanisms between channels (Ivanov et al., 2022; Kong et al., 2019). Modern research on digital warehouse management methods also confirms the complexity of integrating different logistics systems into a single circuit (Ishfaq and Raja, 2017). A vivid illustration of this limitation is modern research on hybrid systems, such as the work of Ishfaq and Raja, where order fulfillment options in retail supply chains are analyzed in detail. Despite the systematic approach to assessing operational trade-offs, the model considers the performance of external partners as a deterministic parameter. In practice, however, this parameter is a key source of uncertainty and requires its own forecasting and integration into the overall risk management system (Egorov et al., 2023; Wiedmer et al., 2021; Ivanov, 2020). Consequently, it can be argued that even in such advanced works, a fragmented approach persists: a specific optimization problem is solved without considering the full architecture of business processes and the dynamic nature of risks inherent in hybrid models.

Thus, the conducted literature analysis reveals a persistent research gap manifesting at three interconnected levels. At the conceptual level, there is a lack of a comprehensive approach to evaluating the effectiveness of a hybrid warehouse architecture as a unified system. At the methodological level, the mathematical framework capable of adequately accounting for the specific risks of virtual warehouses is underdeveloped. However, the application of business intelligence and digital systems in logistics shows potential for creating such integrated models (Iliasgenko et al., 2022). At the practical level, there are no formalized problem statements for optimization to find a balance between profit and risks.

The main purpose of this work is to develop a methodological approach to managing hybrid warehouse architecture, culminating in the formalization of the corresponding optimization task. To achieve this goal, the research solves the following tasks: a comparative analysis of the effectiveness of classical and hybrid models is carried out; a mathematical apparatus is being developed that integrates supplier reliability and risk assessment parameters; the impact of risk accounting on profit is demonstrated using a conditional example.; and, as a key result, a verbal formulation of an optimization problem is formulated, aimed at maximizing profits under given risk constraints and delivery time.

Materials and Methods

The object of this research comprises two architectures for an online store's inventory management system.

Architecture 1: Physical Warehouse Model. This model represents a classic system where the entire product assortment is stored in the company's owned physical warehouse. The order fulfillment process begins with a prepayment to the supplier, followed by the placement of goods in the owned warehouse. Subsequently, the customer places an online order and pays for it. A company employee locates the item in the warehouse, then packages it, prepares the necessary documentation, and hands over the ready order to a courier service for shipment. In this variant, all logistical operations and risks associated with storage and order fulfillment lie entirely with the company.

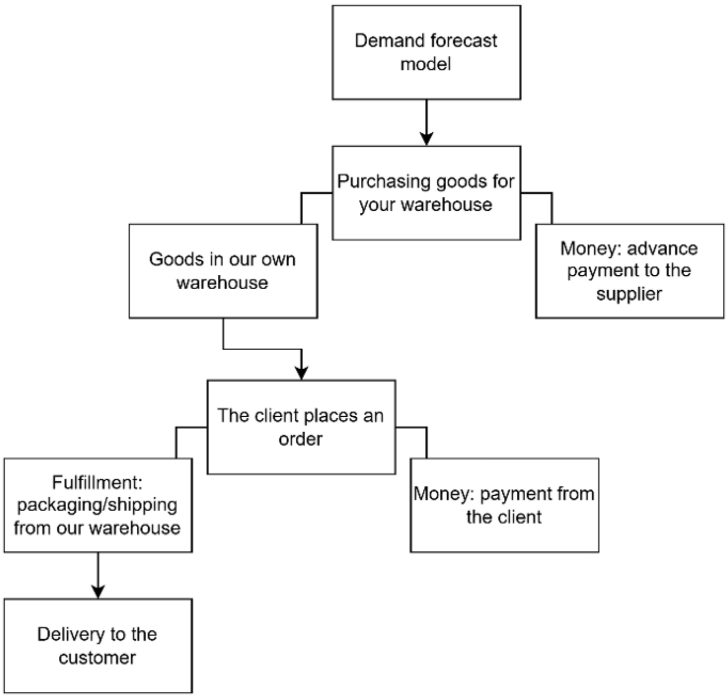

Fig. 1. Business process diagram of the classical inventory management model with a physical warehouse.

Architecture 2: Hybrid Model (Physical + Virtual Warehouse)

The second model involves the operation of an owned warehouse in conjunction with a virtual one. In this case, the virtual warehouse implies a dropshipping scheme. The key difference from the first model is that the company does not own the goods but uses the supplier's product catalog. The supplier, upon receiving an order, ships it directly to the customer from their own warehouse, while the company's warehouse is not involved. Such models, including dropshipping, require careful analysis of the strategic choice between different order fulfillment methods (Gelsomino et al., 2018; Wang et al., 2016).

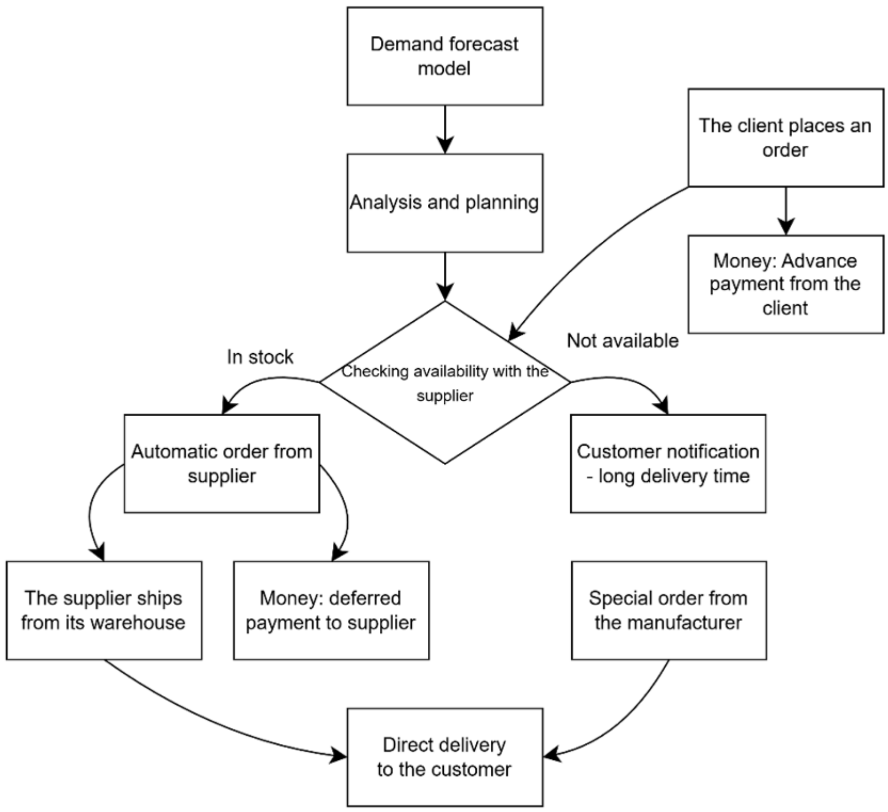

Fig. 2. Business process diagram of the hybrid inventory management model (physical warehouse + virtual warehouse).

To conduct a comparative analysis of the two architectures, a system of indicators was developed, covering key business aspects: financial efficiency, operational activities, and risk management. The choice of indicators is driven by the need to quantitatively assess the trade-offs arising from the integration of a virtual warehouse.

Cash Flow: Assesses the cash conversion cycle. Architecture 1 is characterized by a classic cycle with supplier prepayment. In Architecture 2, a negative conversion cycle arises, where payment from the customer is received before settlement with the supplier, thereby releasing working capital.

Customer Delivery Time: A key parameter of customer experience. For Architecture 1, delivery time is minimal and determined by logistics from the owned warehouse. For Architecture 2, delivery time increases by the supplier's order processing time and logistics from their warehouse, which is a variable.

Risk Structure: Qualitative and quantitative assessment of prevailing risk types. In Architecture 1, operational risks prevail: risks of deadstock and storage costs. In Architecture 2, operational risks are minimized, but partner risks emerge: risk of supplier unreliability (delays, defects) and risk of losing control over the process.

Profitability: Calculated using different formulas for the two models. For Architecture 1: Revenue − (Cost + Carrying Costs). For Architecture 2: Revenue − Supplier Price. The highlighted structure requires a separate calculation for accurate comparison.

Order Fulfillment Logistics Costs: In Architecture 1, costs include the formation of own logistics infrastructure and payroll. In Architecture 2, these costs are minimized and delegated to the supplier but are included in the higher purchase price.

Table 1. Comparative Analysis of Key Architectural Indicators.

Indicator	Architecture 1 (Physical Warehouse)	Architecture 2 (Hybrid Model)	Evaluation Method
Cash Flow	Classic cycle, prepayment to supplier first, then awaiting sale, funds "frozen" in inventory	Negative conversion cycle, payment from customer occurs before supplier settlement, working capital is released	Cash Conversion Cycle analysis
Delivery Time	Minimal, goods physically located at company warehouse, ready for shipment	Increased, variable, depends on supplier's processing speed	Statistical analysis of order fulfillment
Risk Structure	Operational risks: illiquid goods, storage, accounting, and logistics costs, inventory obsolescence	Partner risks: supplier unreliability, delays, defects, loss of process control	Qualitative assessment and quantitative evaluation of probability and cost of risk
Profitability	Revenue – (Cost + Storage Costs)	Revenue – Supplier Price	Calculation based on corresponding formulas using a unified initial data base
Fulfillment Costs	High, include formation of warehouse infrastructure and labor costs	Low/delegated, costs are included in the supplier's price	Analysis of operational cost structure

For the quantitative assessment of the comparative efficiency of the architectures and the subsequent formalization of the optimization problem, a mathematical framework was developed to account for the specific parameters of the hybrid model, primarily the risks associated with the reliability of the virtual warehouse supplier. The following main variables were introduced to formalize the model:

t – current time within the planning period T

$D(t)$ – forecasted demand for the product at time t, obtained from forecasting models

$S_{own}(t)$ – inventory level at the owned (physical) warehouse at time t

$S_{transit}(t)$ – volume of goods ordered from the virtual warehouse supplier and in transit (fulfillment status)

L_v – lead time of the virtual warehouse supplier (time from order placement to shipment to the customer)

β – supplier reliability parameter, probability of fulfilling an order within the agreed time L_v, where $0 \le \beta \le 1$.

R – risk cost estimate, financial losses from one failed delivery, including lost profit and penalties [Lost Profit + Penalties]

$P_{failure}$ – probability of delivery failure (1 – β)

C_{hold} – unit cost of holding one item in the owned warehouse

$Price_{sale}$ – selling price of the product to the end customer

$Cost_{own}$ – cost of goods in the owned warehouse (purchase price)

$Price_{supplier}$ – Product price from the virtual warehouse supplier

Based on the introduced parameters, key calculation formulas were defined:

Total available stock (including goods in transit):

$$S_{total}(t) = S_{own}(t) + S_{transit}(t)$$

Condition for placing a new order:

$$IF\ D(t) > S_{total}(t)\ THEN\ Q_{order} = D(t) - S_{total}(t)$$

where Q_{order} is the order volume.

Supplier risk assessment model:

$$E_{loss} = P_{failure} * R = (1-\beta)*[Lost\ Profit + Penalties]$$

Profit model for comparative analysis:

Architecture 1

$$Profit_1 = (Price_{sale} - Cost_{own} - C_{hold}) * Q_{sold}$$

where Q_{sold} – volume of goods sold

Architecture 2

$$Profit_2 = ((Price_{sale} - Price_{supplier}) * \beta - P_{failure} * R) * Q_{sold}$$

To demonstrate the application of the mathematical framework, an example with conditional initial data is considered. Let:

$Price_{sale}$ = 2000 rub.;

$Price_{supplier}$ = 1200 rub.;

β = 0.95;

R = 1000 rub., where *Lost Profit* = 800 rub., *Penalties* = 200 rub.;

Q_{sold} = 100 units;

Calculation for Architecture 1:

Profit ($Profit_1$): (2000 – 1000 – 50) * 100 = 950 * 100 = 95000 rub.

Calculation for Architecture 2:

Nominal profit (at β = 1): (2000 – 1200) * 100 = 80000 rub.

Expected losses: (1 – 0.95) * 1000 * 100 = 5000 rub.

Adjusted profit ($Profit_2$): 80000 * 0.95 – 5000 = 71000 rub.

The example clearly demonstrates that even with high supplier reliability (β = 0.95) accounting for risk reduces expected profit by 11.25% compared to the nominal calculation, confirming the necessity of using adjusted models for managerial decision-making. The developed mathematical apparatus makes it possible to quantify the comparative effectiveness of architectures using approaches similar to those used in modern research on hybrid supply chains (Li et al., 2022; Winkelmann and Spinler, 2022), as well as considering the evolution of digital systems in the economy through the adoption of multi-agent technologies (Antonov et al., 2025).

Results and Discussion

Based on the developed methodological approach and mathematical framework, results were obtained enabling a comprehensive comparative analysis of the two architectures and the formalization of the optimization problem as a verbal problem statement. Thanks to the practical example with conditional data, systemic differences between the two architectures can be identified. The key identified trade-offs include:

Liquidity vs. Risk Trade-off: The hybrid architecture demonstrates a significant (up to 40% in the considered example) release of working capital due to the negative cash conversion cycle. However, this advantage is offset by an increase in operational risks associated with supplier reliability. At β < 0.9, the aggregate risk of the hybrid model may exceed that of the classical architecture. This compromise is consistent with the results of research on working capital management in conditions of uncertain demand (Levina et al., 2023). The observed reduction in operating costs when delegating fulfillment also corresponds to the conclusions of studies analyzing the effectiveness of outsourcing logistics services (Mohamed-Iliasse et al., 2022).

Speed vs. Assortment Trade-off: The hypothesis that the hybrid model allows for expanding the assortment matrix by 25-30% without increasing storage costs is confirmed. The "price" for this is an increase in the average delivery time for goods from the virtual warehouse by 2-3 days, which is critical for "impulse buy" product categories.

Control vs. Cost Trade-off: Delegating fulfillment to the supplier in the hybrid model leads to a 15-20% reduction in operational logistics costs. At the same time, a "coordination cost" arises—requiring investments in IT infrastructure for integrating and monitoring supplier order fulfillment. Research in effective multimodal logistics management emphasizes the importance of such investments for creating resilient hybrid systems (de Assis et al., 2024).

The table below presents the results of a comparative experiment with different levels of supplier reliability.

Table 2. Comparative Analysis of Profitability Under Different Supplier Reliability Scenarios .

Scenario (Reliability β)	Profit Architecture 1, rub.	Adjusted Profit Architecture 2, rub.	Expected Loss E_{loss}, rub.	Profit Deviation, %
Low Reliability (β = 0.85)	95 000	53 000	15 000	-44.2%
Medium Reliability (β = 0.90)	95 000	62 000	10 000	-34.7%
High Reliability (β = 0.95)	95 000	71 000	5 000	-25.3%
Ideal Supplier (β = 1.00)	95 000	80 000	0	-15.8%

The "Profit Deviation" column shows the percentage by which the profit of the hybrid model differs from the profit of the classical physical warehouse model. A negative value indicates that the hybrid model's profit is lower; this deviation demonstrates the price of the trade-off: we gain the advantages of the hybrid model in the form of released working capital and reduced risks of deadstock, but pay for it with a portion of the profit. The magnitude of this deviation directly depends on the supplier's reliability; the higher the β, value, the smaller the profitability gap between the two architectures. Based on such results, it is impossible to draw an unambiguous conclusion about the advantage of one architecture over the other, which emphasizes the necessity of an optimization approach. The problem statement is formulated concerning control variables – the vector *X*, characterizing the system configuration (e.g., distribution of the product assortment between physical and virtual channels, selection of suppliers, and determination of safety stock levels). The objective is to maximize the system's expected adjusted profit $P_{total}(X)$, which is the sum of the profit from the physical warehouse and the adjusted profit from the virtual channel, calculated considering the risk of supplier unreliability. For this objective function, the following constraints are identified:

The system's aggregate risk $R_{total}(X)$, calculated based on supplier reliability parameters (β) and the risk cost estimate *(R)*, must not exceed a set threshold $R_{\max}$.

The weighted average delivery time across all channels $T_{avg}(X)$ must not exceed the maximum allowable term $T_{\max}$, defined by the service policy.

The configuration *X* must satisfy constraints on the available volume of working capital and the storage capacity of the physical warehouse. The mathematical formulation is as follows: $P_{total}(X) \to \max$ subject to $R_{total}(X) \le R_{\max}$, $T_{avg}(X) \le T_{\max}$, $X \in \Omega$ (feasible resource region).

The formulated optimization problem statement is a logical outcome of the conducted analysis and offers a path to overcoming the identified trade-offs. The scientific novelty lies in the comprehensive approach to managing a hybrid warehouse architecture. Unlike classical models, the proposed formulation explicitly integrates key virtual warehouse parameters – supplier reliability and risk cost estimate – into the objective function and constraints. This allows not only for stating the existence of the "Liquidity vs. Risk" trade-off but also for managing it on a formal mathematical basis, finding a system configuration that maximizes profit at an acceptable risk level. The practical significance is that the model provides managers with a structured tool for strategic decision-making. Instead of an intuitive choice between architectures, it becomes possible to calculate the optimal allocation of assortment and resources. For example, calculation results similar to those presented in the table above show that including virtual warehouse goods in the assortment at $\beta > 0.9$ can be justified from a total risk perspective, while goods from unreliable suppliers $\beta < 0.85$ should be excluded or transferred to the physical warehous Within this work, the problem is presented in a verbal form. Its practical implementation requires solving a number of additional tasks. First, it is necessary to develop algorithms for numerical solution using methods of nonlinear or stochastic programming, accounting for the probabilistic nature of the parameter β. Second, the collection and analysis of real operational data for model calibration – empirical estimation of β and R values for various suppliers and product categories – is a relevant task. This defines promising directions for further research. For predicting future demand and inventory levels, the use of machine learning methods is planned, which are also successfully used in logistics (Nalgozhina and Uskenbayeva, 2023; Ilin et al., 2022), and automating hybrid business processes with RPA can optimize warehouse management (Egorov et al., 2021). For solving optimization problems, one could use, for example, the Pyomo library (https://www.pyomo.org/) for Python or other tools.

Conclusion

This work developed a comprehensive methodology for the comparative analysis of classical and hybrid warehouse architectures, including a system of financial, operational, and risk-oriented indicators. A mathematical framework was created, whose key element is the integration of risk parameters into the profit model. Using a conditional example, it was shown that accounting for risk significantly affects comparative efficiency. A verbal formulation of the optimization problem for managing a hybrid warehouse architecture was formulated, and promising directions for further research were identified. The conducted research demonstrates that the choice between classical and hybrid warehouse architecture represents a complex trade-off. As the comparative analysis showed, the reduction in operational costs and the release of working capital in the hybrid model are accompanied by a significant decrease in profitability, the magnitude of which directly depends on supplier reliability. This conclusion underscores the impossibility of a universal solution and confirms the necessity of an optimization approach to managing hybrid systems. The optimization problem statement developed in this work allows for overcoming the identified limitations.

REFERENCES

Antonov, A., Levina, A., Zhao, Z. 2025. Evolution of digital systems in the economy through the adoption of multi-agent technologies. In: Ilin, I., Youzhong, M. (eds.) Digital Systems and Information Technologies in the Energy Sector. DITES 2024. Lecture Notes in Networks and Systems 1244, 171–184. Springer, Cham. https://doi.org/10.1007/978-3-031-80710-7_14

Babkina A. 2024. Information investment platform as an improvement tool for investment climate of warehouse real estate. Technoeconomics 3, 2 (9), 85–98. DOI: https://doi.org/10.57809/2024.3.2.9.7

Christopher, M. 2016. Logistics & Supply Chain Management. 5th edn. Pearson, Harlow.

de Assis, R.F., Faria, A.F., Thomasset-Laperrиre, V., Santa-Eulalia, L.A., Ouhimmou, M., Ferreira, W.P. 2024. Machine learning in warehouse management: A survey. Procedia Computer Science 232, 2686–2695. https://doi.org/10.1016/j.procs.2024.02.096

Egorov, D., Levina, A., Kalyazina, S., Schuur, P., Gerrits, B. 2021. The challenges of the logistics industry in the era of digital transformation. In: Arseniev, D.G., et al. (eds.) Cyber-Physical Systems and Control. CPS&C 2020. Lecture Notes in Networks and Systems 259, 301–311. Springer, Cham. https://doi.org/10.1007/978-3-030-87966-2_27

Egorov, D., Shaban, A., Levina, A., Schuur, P., Gerrits, B., Levin, I. 2023. Digital methods of warehouse logistics as a tool to accelerate supply chains. In: Mottaeva, A. (ed.) E3S Web of Conferences 371, 05062. https://doi.org/10.1051/e3sconf/202337105062

Gelsomino, L.M., de Boer, R., Steeman, M., Perego, A. 2018. An optimisation strategy for concurrent Supply Chain Finance schemes. Journal of Purchasing and Supply Management 24(3), 201–211. https://doi.org/10.1016/j.pursup.2018.07.004

Gou, Q., Sethi, S., Yue, J., Zhang, J. 2016. Push and pull contracts in a local supply chain with an outside market. Decision Sciences 47(4), 625–653. DOI: https://doi.org/10.1111/deci.12209

Hasan, M.R., Daryanto, Y., Triki, C., Elomri, A. 2024. An inventory model of e-marketplace with a promotional program. Journal of Modelling in Management 19(3), 787–805. https://doi.org/10.1108/JM2-01-2023-0011

Iliashenko, V., Ilin, I., Schuur, P., Gerrits, B., Kalyazina, S., Esser, M. 2022. Business intelligence systems application in transport and logistics companies. In: Arseniev, D.G., et al. (eds.) Cyber-Physical Systems and Control II. CPS&C 2021. Lecture Notes in Networks and Systems 460, 670–680. Springer, Cham. https://doi.org/10.1007/978-3-031-20875-1_62

Ilin, I., Levina, A., Frolov, K. 2022. Innovative ecosystem model of vaccine lifecycle management. Journal of Open Innovation: Technology, Market, and Complexity 8(1), 5. https://doi.org/10.3390/joitmc8010005

Ivanov, D. 2020. Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. Transportation Research Part E: Logistics and Transportation Review 136, 101922. https://doi.org/10.1016/j.tre.2020.101922

Ivanov, D., Dolgui, A., Sokolov, B. 2022. Cloud supply chain: Integrating Industry 4.0 and digital platforms in the "Supply Chain-as-a-Service". Transportation Research Part E: Logistics and Transportation Review 160, 102676. https://doi.org/10.1016/j.tre.2022.102676

Ishfaq, R., Raja, U. 2017. Evaluation of order fulfillment options in retail supply chains. Decision Sciences 48(5), 866–894. https://doi.org/10.1111/deci.12277

Kong, X.T.R., Huang, G.Q., Du, M.L. 2019. A physical emulation model of cellular warehousing for e-commerce logistics. Procedia CIRP 81, 826–831. https://doi.org/10.1016/j.procir.2019.03.095

Levina, A., Frolov, K., Trifonova, N., Tick, A. 2023. Effective management of multimodal logistics in Russia. In: Ilin, I., et al. (eds.) Digital Technologies in Logistics and Infrastructure. DTLI 2023. Lecture Notes on Data Engineering and Communications Technologies 157, 279–291. Springer, Cham. https://doi.org/10.1007/978-3-031-24434-6_24

Li, G., Li, L., Sethi, S.P., Guan, X. 2022. Drop-shipping or self-holding? Strategic selection of the online fulfillment mode under competition. International Journal of Production Economics 244, 108380. https://doi.org/10.1016/j.ijpe.2021.108380

Li, M., Mizuno, S. 2022. A dual-channel supply chain model with inventory management. International Journal of Production Economics 244, 108382. https://doi.org/10.1016/j.ejor.2022.02.049

Mohamed-Iliasse, M.L., Benabbou, A., Berrado, A. 2022. Machine learning in supply chain management: A systematic literature review. International Journal of Supply and Operations Management 9(1), 1–22. https://doi.org/10.22034/ijsom.2021.109189.2279

Nalgozhina, N., Uskenbayeva, R. 2023. Automating hybrid business processes with RPA: optimizing warehouse management. Procedia Computer Science 221, 1474–1481. https://doi.org/10.1016/j.procs.2023.12.223

Soleimani, F., Pirayesh, M., Dehghanian, F. 2020. An integrated production-inventory model for a dual-channel supply chain. International Journal of Industrial Engineering & Production Research 31(3), 341–354.

Vandeput, N. 2020. Inventory optimization: Models and simulations. De Gruyter, Berlin.

Wang, Y., Zhang, D., Liu, Q., Shen, F., Lee, L.H. 2016. Towards enhancing the last-mile delivery: An effective crowd-tasking model with scalable solutions. Transportation Research Part E: Logistics and Transportation Review 93, 279–297. https://doi.org/10.1016/j.tre.2016.06.002

Wiedmer, R., Rogers, Z.S., Polyviou, M., Mena, C., Chae, S. 2021. The dark and bright sides of complexity: A dual perspective on supply network resilience. Journal of Business Logistics 42(3), 336–359. https://doi.org/10.1111/jbl.12264

Winkelmann, S., Spinler, S. 2022. The value of drop-shipping for managing demand uncertainty in e-commerce. Business Research 15(1), 267–296. https://doi.org/10.1007/s40685-021-00193-7

Xu, S., Tang, H., Lin, Z. 2021. Inventory and ordering decisions in dual-channel supply chains involving free riding and consumer switching behavior with supply chain financing. Mathematical Problems in Engineering 2021, 5530124. https://doi.org/10.1155/2021/5530124

СПИСОК ИСТОЧНИКОВ

Antonov, A., Levina, A., Zhao, Z. 2025. Evolution of digital systems in the economy through the adoption of multi-agent technologies. In: Ilin, I., Youzhong, M. (eds.) Digital Systems and Information Technologies in the Energy Sector. DITES 2024. Lecture Notes in Networks and Systems 1244, 171–184. Springer, Cham. https://doi.org/10.1007/978-3-031-80710-7_14

Babkina A. 2024. Information investment platform as an improvement tool for investment climate of warehouse real estate. Technoeconomics 3, 2 (9), 85–98. DOI: https://doi.org/10.57809/2024.3.2.9.7

Christopher, M. 2016. Logistics & Supply Chain Management. 5th edn. Pearson, Harlow.

de Assis, R.F., Faria, A.F., Thomasset-Laperrиre, V., Santa-Eulalia, L.A., Ouhimmou, M., Ferreira, W.P. 2024. Machine learning in warehouse management: A survey. Procedia Computer Science 232, 2686–2695. https://doi.org/10.1016/j.procs.2024.02.096

Egorov, D., Levina, A., Kalyazina, S., Schuur, P., Gerrits, B. 2021. The challenges of the logistics industry in the era of digital transformation. In: Arseniev, D.G., et al. (eds.) Cyber-Physical Systems and Control. CPS&C 2020. Lecture Notes in Networks and Systems 259, 301–311. Springer, Cham. https://doi.org/10.1007/978-3-030-87966-2_27

Egorov, D., Shaban, A., Levina, A., Schuur, P., Gerrits, B., Levin, I. 2023. Digital methods of warehouse logistics as a tool to accelerate supply chains. In: Mottaeva, A. (ed.) E3S Web of Conferences 371, 05062. https://doi.org/10.1051/e3sconf/202337105062

Gelsomino, L.M., de Boer, R., Steeman, M., Perego, A. 2018. An optimisation strategy for concurrent Supply Chain Finance schemes. Journal of Purchasing and Supply Management 24(3), 201–211. https://doi.org/10.1016/j.pursup.2018.07.004

Gou, Q., Sethi, S., Yue, J., Zhang, J. 2016. Push and pull contracts in a local supply chain with an outside market. Decision Sciences 47(4), 625–653. DOI: https://doi.org/10.1111/deci.12209

Hasan, M.R., Daryanto, Y., Triki, C., Elomri, A. 2024. An inventory model of e-marketplace with a promotional program. Journal of Modelling in Management 19(3), 787–805. https://doi.org/10.1108/JM2-01-2023-0011

Iliashenko, V., Ilin, I., Schuur, P., Gerrits, B., Kalyazina, S., Esser, M. 2022. Business intelligence systems application in transport and logistics companies. In: Arseniev, D.G., et al. (eds.) Cyber-Physical Systems and Control II. CPS&C 2021. Lecture Notes in Networks and Systems 460, 670–680. Springer, Cham. https://doi.org/10.1007/978-3-031-20875-1_62

Ilin, I., Levina, A., Frolov, K. 2022. Innovative ecosystem model of vaccine lifecycle management. Journal of Open Innovation: Technology, Market, and Complexity 8(1), 5. https://doi.org/10.3390/joitmc8010005

Ivanov, D. 2020. Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. Transportation Research Part E: Logistics and Transportation Review 136, 101922. https://doi.org/10.1016/j.tre.2020.101922

Ivanov, D., Dolgui, A., Sokolov, B. 2022. Cloud supply chain: Integrating Industry 4.0 and digital platforms in the "Supply Chain-as-a-Service". Transportation Research Part E: Logistics and Transportation Review 160, 102676. https://doi.org/10.1016/j.tre.2022.102676

Ishfaq, R., Raja, U. 2017. Evaluation of order fulfillment options in retail supply chains. Decision Sciences 48(5), 866–894. https://doi.org/10.1111/deci.12277

Kong, X.T.R., Huang, G.Q., Du, M.L. 2019. A physical emulation model of cellular ware-

housing for e-commerce logistics. Procedia CIRP 81, 826–831. https://doi.org/10.1016/j.procir.2019.03.095
Levina, A., Frolov, K., Trifonova, N., Tick, A. 2023. Effective management of multimodal logistics in Russia. In: Ilin, I., et al. (eds.) Digital Technologies in Logistics and Infrastructure. DTLI 2023. Lecture Notes on Data Engineering and Communications Technologies 157, 279–291. Springer, Cham. https://doi.org/10.1007/978-3-031-24434-6_24
Li, G., Li, L., Sethi, S.P., Guan, X. 2022. Drop-shipping or self-holding? Strategic selection of the online fulfillment mode under competition. International Journal of Production Economics 244, 108380. https://doi.org/10.1016/j.ijpe.2021.108380
Li, M., Mizuno, S. 2022. A dual-channel supply chain model with inventory management. International Journal of Production Economics 244, 108382. https://doi.org/10.1016/j.ejor.2022.02.049
Mohamed-Iliasse, M.L., Benabbou, A., Berrado, A. 2022. Machine learning in supply chain management: A systematic literature review. International Journal of Supply and Operations Management 9(1), 1–22. https://doi.org/10.22034/ijsom.2021.109189.2279
Nalgozhina, N., Uskenbayeva, R. 2023. Automating hybrid business processes with RPA: optimizing warehouse management. Procedia Computer Science 221, 1474–1481. https://doi.org/10.1016/j.procs.2023.12.223
Soleimani, F., Pirayesh, M., Dehghanian, F. 2020. An integrated production-inventory model for a dual-channel supply chain. International Journal of Industrial Engineering & Production Research 31(3), 341–354.
Vandeput, N. 2020. Inventory optimization: Models and simulations. De Gruyter, Berlin.
Wang, Y., Zhang, D., Liu, Q., Shen, F., Lee, L.H. 2016. Towards enhancing the last-mile delivery: An effective crowd-tasking model with scalable solutions. Transportation Research Part E: Logistics and Transportation Review 93, 279–297. https://doi.org/10.1016/j.tre.2016.06.002
Wiedmer, R., Rogers, Z.S., Polyviou, M., Mena, C., Chae, S. 2021. The dark and bright sides of complexity: A dual perspective on supply network resilience. Journal of Business Logistics 42(3), 336–359. https://doi.org/10.1111/jbl.12264
Winkelmann, S., Spinler, S. 2022. The value of drop-shipping for managing demand uncertainty in e-commerce. Business Research 15(1), 267–296. https://doi.org/10.1007/s40685-021-00193-7
Xu, S., Tang, H., Lin, Z. 2021. Inventory and ordering decisions in dual-channel supply chains involving free riding and consumer switching behavior with supply chain financing. Mathematical Problems in Engineering 2021, 5530124. https://doi.org/10.1155/2021/5530124

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Статья поступила в редакцию 14.11.2025; одобрена после рецензирования 26.11.2025; принята к публикации 11.12.2025.
The article was submitted 14.11.2025; approved after reviewing 26.11.2025; accepted for publication 11.12.2025.