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The cost-effectiveness of the drop-and-hook model as a tool for increasing the resilience and continuity of interregional supply chains in the United States

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Abstract. *The transformation of modern supply chains is accompanied by increasing demands for speed, flexibility and reliability of transport and logistics processes. In the USA, where interregional transportation plays a key role in the economy, delivery organization models that minimize transport downtime and ensure the stability of cargo flows are particularly important. One such approach is the drop-and-hook model, which relies on the operational replacement of trailers without long wait times during loading or unloading.*

The purpose of the study is to analyze the economic results of applying the drop-and-hook model in the USA interregional transportation system and determine its impact on the efficiency and continuity of supply chains. The study is based on a combination of theoretical and empirical methods, including analysis, synthesis, abstraction, induction and deduction for theoretical justification, as well as statistical analysis of efficiency indicators of transport and logistics operations.

Theoretical analysis of the effectiveness of the drop-and-hook model has shown its positive impact on the optimization of transport and logistics processes, particularly through reduced vehicle downtime, more rational resource use and lower operating costs in interregional transportation. The drop-and-hook model increases the adaptability and resilience of supply chains to logistical risks, ensuring the stability of transportation and reducing the time required to restore operational processes after delays. However, potential limitations of this model's implementation have also been identified, in particular, high requirements for schedule coordination and the need for significant initial investments.

Thus, it has been established that the drop-and-hook model has significant potential to increase the economic efficiency and resilience of interregional supply chains in the United States. It allows for optimizing costs, reducing downtime and improving the reliability of supplies. Implementing this model can be an important step for companies seeking to adapt to changing market conditions and increase competitiveness.

Keywords: *transport and logistics processes, freight transportation, operational replacement of trailers, logistics risks, transport adaptability, cost optimization, continuity of supply, transport downtime, competitiveness of carriers, delivery management.*

Економічна ефективність моделі drop-and-hook як інструменту підвищення стійкості та безперервності міжрегіональних ланцюгів постачання у США

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Анотація. *Трансформація сучасних ланцюгів постачання супроводжується зростанням вимог до швидкості, гнучкості та надійності транспортно-логістичних процесів. У США, де міжрегіональні перевезення відіграють ключову роль у функціонуванні економіки, особливого значення набувають моделі організації доставки, здатні мінімізувати простої транспорту та забезпечити стабільність вантажопотоків. Одним із таких підходів є модель drop-and-hook, яка ґрунтується на оперативній заміні причепів без тривалого очікування під час навантаження чи розвантаження.*

Мета дослідження полягає в аналізі економічних результатів застосування моделі drop-and-hook у системі міжрегіональних перевезень США та визначенні її впливу на ефективність і безперервність ланцюгів постачання. Дослідження базується на комбінації теоретичних і емпіричних методів, включаючи аналіз, синтез, абстрагування, індукцію та дедукцію для теоретичного обґрунтування, а також статистичний аналіз показників ефективності транспортно-логістичних операцій.

Теоретичний аналіз ефективності моделі drop-and-hook засвідчив її позитивний вплив на оптимізацію транспортно-логістичних процесів, зокрема через скорочення простоїв транспортних засобів, раціональніше використання ресурсів і зниження операційних витрат у міжрегіональних перевезеннях. Показано, що модель drop-and-hook підвищує адаптивність і стійкість ланцюгів постачання до логістичних ризиків, забезпечуючи стабільність виконання перевезень і скорочення часу відновлення операційних процесів після виникнення затримок. Проте, виявлено й потенційні обмеження впровадження цієї моделі, зокрема високі вимоги до координації графіків та необхідність значних початкових інвестицій.

Отже, встановлено, що модель drop-and-hook демонструє значний потенціал для підвищення економічної ефективності та стійкості міжрегіональних ланцюгів постачання в США. Вона дозволяє оптимізувати

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витрати, скоротити час простою та підвищити надійність поставок. Впровадження цієї моделі може стати важливим кроком для компаній, які прагнуть адаптуватися до мінливих умов ринку та підвищити свою конкурентоспроможність.

Ключові слова: *транспортно-логістичні процеси, вантажні перевезення, оперативна заміна причепів, логістичні ризики, адаптивність перевезень, оптимізація витрат, безперервність поставок, простої транспорту, конкурентоспроможність перевізників, управління доставкою.*

Problem statement. In the modern globalized economy, interregional supply chains combine transport hubs, warehouses and distribution centers across different countries, leading to increased demands for the efficiency of logistics processes. Under such conditions, the search for organizational solutions that ensure the continuity of transportation, reduce transport downtime and increase the reliability of cargo delivery becomes particularly important. One such solution is the drop-and-hook model, which allows semi-trailers to be promptly replaced at terminals without loading or unloading at the point of arrival.

The study's relevance stems from the need to adapt transport and logistics systems to modern challenges, including rising fuel costs, increased environmental requirements, supply chain instability and greater transportation flexibility. In this regard, there is a growing practical interest in delivery organization models that ensure more rational use of resources and increase the efficiency of logistics operations.

Despite the widespread adoption of the drop-and-hook model in road transportation, scientific research has not given sufficient attention to assessing its economic benefits and its impact on the sustainability of supply chains. Existing works mainly focus on the organizational aspects of the model's functioning, while the issues of its role in ensuring transportation continuity, reducing unproductive

time costs and increasing the adaptability of logistics systems require further research.

Thus, studying the functioning of the drop-and-hook model is important for identifying opportunities to increase the efficiency of interregional transportation, optimize the use of transport resources, and ensure the stability of logistics processes amid modern market changes.

Analysis of recent studies and publications. The economic efficiency of the drop-and-hook model in increasing the sustainability and continuity of interregional supply chains in the USA is considered in modern research as a component of the transformation of transport and logistics systems aimed at reducing unproductive time, optimizing the use of rolling stock, and increasing transportation capacity. The work of S. Shiri, N. Huynh, D. Smith, and F. Harder [1] emphasizes the importance of port and terminal facilities in the formation of an efficient drayage transportation system, where the use of approaches close to drop-and-hook reduces cargo processing delays and increases the stability of logistics operations. Similar conclusions were obtained in the study by M. Shao, D. Chen, X. Lu, X. Liu, and Z. Yang [2], which analyzes the drop-and-pull model and demonstrates its economic feasibility under the condition of proper infrastructure, relevant to the organization of interregional flows in the USA.

The work of A. Mohan and P. Vaishnav [3] found that the automation of freight transportation in the USA directly reduces operating costs and increases the efficiency of transport networks, which is conceptually consistent with the principles of drop-and-hook as a model for minimizing downtime. In turn, I. P. Fomichenko and S. O. Barkova [4] consider smart logistics as a tool for digital transformation of transport processes, which ensures increased manageability and efficiency of logistics systems through the integration of information technologies.

The issue of supply chain sustainability is detailed in the study by O. A. Tsymbalistova, Y. V. Yudenko, and O. S. Chernikhova [5], which

emphasizes that the ability of logistics systems to adapt to external risks depends on the flexibility of the organization of transport flows, which is directly correlated with the advantages of drop-and-hook in ensuring the continuity of transportation.

The study by O. Korostin [6] demonstrates the role of artificial intelligence in optimizing transportation routes, which enhances the efficiency of logistics models by reducing costs and increasing planning accuracy. Planning accuracy and resource efficiency are also improved. In the works of G. G. Tolobaiev [7; 8], attention is focused on the digitalization and decarbonization of the transport industry as factors for increasing the economic and environmental efficiency of transportation.

An important contribution to the understanding of the digital transformation of logistics is made by V. Ishchenko [9], who demonstrates that the efficiency of modern logistics systems is determined by the use of algorithmic flow management models, which create the prerequisites for implementing drop-and-hook solutions in large-scale transport networks. A general approach is presented in the study by S. Smerichevskyi, O. Mykhalchenko, Z. Poberezhna, and I. Kryvovyazyuk [10], which emphasizes that the implementation of innovative technologies in transport enterprises is a key factor in ensuring their sustainability and the continuity of operations.

Thus, the analysis of the literature shows that the drop-and-hook model is considered as an element of modern logistics modernization, integrated into the processes of digitalization and automation of transport systems; however, its economic efficiency and impact on the sustainability of interregional supply chains, in particular in the USA, remain insufficiently empirically substantiated, which determines the need for further research.

Identification of previously unresolved parts of the general problem. Despite the availability of theoretical developments, the practical results of applying the drop-and-hook model in enterprise activities and in interregional transportation remain insufficiently confirmed due to the limited number of systematic

observations, the lack of agreed assessment approaches, and the lack of comparative data. This makes it difficult to determine its real impact on costs, supply continuity and environmental indicators, hindering the justified implementation of the model in practical activities. Eliminating these gaps is important for improving the efficiency of logistics processes and for making better management decisions.

Formulation of the article objectives (task statement). The purpose of the study is to determine the economic efficiency of the drop-and-hook model as a tool for increasing the sustainability and continuity of interregional supply chains in the USA, and to justify its feasibility in the context of modern logistics challenges.

Research objectives:

1. To analyze the essence and organizational and economic features of the drop-and-hook model in the USA road transportation system.

2. To assess the impact of using the drop-and-hook model on key indicators of the efficiency of logistics processes (costs, downtime, transport productivity, reliability of supplies).

3. To investigate the role of the drop-and-hook model in increasing the sustainability and continuity of interregional supply chains in conditions of risks and crisis situations.

Presentation of the main material of the study. The drop-and-hook model is an organizational form of road transportation that separates the transportation process from loading and unloading operations. The essence of the approach is that the driver delivers a trailer to the destination, leaves it for cargo processing, and immediately hooks up another one, ready for transportation, thereby minimizing tractor downtime and ensuring the continuity of vehicle traffic. From an economic point of view, the model contributes to increasing the efficiency of transport companies' resource use. Reducing waiting time increases the number of trips without expanding the fleet, thereby boosting productivity and reducing costs per

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unit of transportation [11]. In addition, personnel work is optimized, as drivers spend less time waiting and can focus on direct cargo transport.

A characteristic feature of this model is the need for a developed logistics infrastructure: warehouses, distribution centers and specially equipped sites for exchanging trailers. Coordination of all participants' actions in the supply chain is important because efficiency depends on the timely readiness of cargo and accurate planning of transportation schedules.

At the same time, implementing the model is associated with certain limitations. It requires investment in a fleet of trailers and a logistics management system. The model is most effective in large transport networks with stable freight flows, whereas in irregular transportation, its advantages may be less noticeable. In general, drop-and-hook provides increased flexibility, reliability and continuity in interregional supply chains, making it an important tool in modern logistics [12].

A summary of the key characteristics, advantages and limitations of this model is presented in Table 1, which allows for a comprehensive assessment of its organizational and economic efficiency in the context of interregional transportation.

Table 1

Organizational and economic features of the drop-and-hook model in the USA road transportation system

Aspect	Characteristics	Economic effect	Potential limitations
Organization of the transportation process	The driver leaves a trailer at the warehouse and picks up another already loaded one	Reduction of transport downtime	Need for schedule coordination
Use of rolling stock	Separate management of tractors and trailers	Increase in trailer and tractor turnover	Need for more trailers
Service time	Minimization of waiting time for loading/unloading	Increase in driver productivity	Dependence on cargo readiness

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Aspect	Characteristics	Economic effect	Potential limitations
Logistics costs	Optimization of operating costs due to faster turnover	Reduction in costs per unit of transportation	High initial investment
Infrastructure	Use of distribution centers and hubs	Improving transportation planning	Need for a developed logistics network
Transportation flexibility	The ability to quickly change routes and trailers	Increased adaptability to changes in demand	Management complexity
Impact on drivers	Reduced waiting times, clear schedules	Increased labor efficiency	Need for accurate time management
Risks and continuity	Ensuring the continuous movement of goods	Increased resilience of supply chains	Risks of delays in case of inconsistency

Source: author's own development [13–19]

Thus, the organizational and economic features of the drop-and-hook model in the USA road transportation system demonstrate how the structure of logistics operations is changing and under what conditions efficiency is improved. This model is based on the division of functions between transportation and cargo handling, at a terminal, for example, at a Walmart distribution center in Texas or a FedEx hub in Georgia, the driver leaves an already uncoupled trailer and immediately connects another one, prepared for shipment. This scheme ensures continuous tractor movement but requires synchronization between the warehouse and the transport dispatch center, as a delay at any stage immediately disrupts the entire schedule [13].

In the practice of rolling stock management in the USA, a model of separate use of tractors and trailers is used, which allows for a significantly increased intensity of vehicle operation. With this approach, one tractor can sequentially service several trailers throughout the day, reducing downtime and increasing transportation throughput. At the same time, the efficiency of processes in this organization of work depends on the availability of a sufficient reserve of trailers at

logistics sites, as their shortage leads to «bottlenecks» and downtime in transport hubs [14].

Analysis of the time parameters of loading and unloading shows that the duration of operations on ramps is reduced to several minutes, in contrast to the traditional model, where loading can last more than an hour [15]. For example, in the Amazon Logistics network in Illinois, this allows for increasing the number of trips without involving additional drivers, but the effect is achieved only on condition that the cargo is pre-formed and ready for shipment [16].

From a cost perspective, faster trailer turnover, particularly in the FedEx Freight system, reduces the cost per trip, since transport does not stand idle during loading [17]. At the same time, when implementing such a model, companies are forced to invest in additional trailers and digital planning systems, which increases start-up costs, especially for medium-scale carriers.

Of these conditions, the infrastructure component becomes crucial, as the model's effectiveness is observed mainly in large logistics hubs [18], such as Chicago and Atlanta, where networks of cross-docking centers operate. In regions with less developed infrastructure, coordinating trailer exchanges becomes more difficult, reducing the overall stability of the process.

The flexibility of transportation enabled by drop-and-hook manifests in the ability to quickly reorient cargo flows, for example, during peak demand periods before the holidays in the USA. This allows networks such as Amazon and Walmart to quickly redistribute trailers between regions. However, such mobility requires complex dispatching systems, as the number of real-time route changes increases [19].

In the context of driver work organization, as shown by Schneider National, the model reduces warehouse downtime and enables clear shift planning, but it also increases the need for adherence to schedules, since the delay of one tractor affects the entire logistics link [20].

As can be seen, the continuity of transportation in the drop-and-hook system is achieved only under the condition of high coordination among terminals, transport companies and warehouse centers, while any failures in this interaction quickly lead to the accumulation of delays and a decrease in the stability of the entire supply chain. The implementation of the drop-and-hook model has shown a tangible impact on key indicators of logistics process efficiency in interregional transportation in the USA, particularly by reducing costs and downtime for tractors (table 2).

Table 2

Change in operational efficiency of trucking in the USA with the introduction of drop-and-hook (2018–2025)

Indicator	Before implementation	After implementation	Effect, %
Average costs per trip, $	1 250	1 050	−16.0
Idle time of the tractor, h/day	3.2	1.1	−65.6
Number of trips per tractor per month	18	24	+33.3
Reliability of deliveries (% of deliveries without delays)	87.4	95.2	+7.8

Source: author's own calculations [20–23]

The recorded decrease in the average cost of one trip from 1250 to 1050 $ is not formed in the abstract, but in specific operational conditions, when, for example, a driver delivering goods to a regional warehouse of a supermarket chain does not wait for the unloading to be completed, but immediately leaves a loaded trailer and picks up another one that has already been prepared, which allows avoiding several hours of delays and reducing costs for labor and fuel.

In the same operational environment, reducing the daily downtime of tractors from 3.2 to 1.1 hours acquires practical meaning in the operation of terminals with high cargo processing intensity, where previously transport was idle in queues under the ramps, while after the transition to drop-and-hook, the tractor actually performs only the function of delivery between network nodes, handing over the trailer for

processing to warehouse personnel, which allows returning transport to the line much faster.

This time saving directly translates into an increase in the number of trips made by one tractor unit per month, from 18 to 24, which is well illustrated by the example of long-distance transportation between large logistics hubs, when the same vehicle can make more cycles between, conditionally, the central warehouse and regional distribution centers during the week, without wasting time waiting for loading at each point.

In parallel, delivery reliability is improving, which is manifested in an increase in the share of trips made without delays, from 87.4% to 95.2%, and this is reflected in cooperation with manufacturing enterprises, where compliance with component supply schedules is critically important, since the timely arrival of the trailer allows avoiding downtime of production lines and additional costs.

The cumulative effect of these changes demonstrates that the use of the drop-and-hook model in the practice of American carriers is not limited to a technical replacement of the method of handling trailers, but actually restructures the logic of interaction between drivers, warehouses and customers, ensuring consistency of all stages of transportation and creating the prerequisites for scaling this model in other logistics segments. Table 3 summarizes the results of assessing the impact of the drop-and-hook model on ensuring the stability and continuity of the functioning of interregional supply chains in the USA in the context of crisis disruptions that arise under the influence of logistical overloads, driver shortages, restrictions on the operation of warehouse infrastructure and the growth of uneven cargo flows. The consideration is carried out through the prism of changes in the organization of transportation, in which the separation of the transportation process from loading and unloading operations reduces the dependence of tractor movement on conditions at individual terminals and ensures a more predictable delivery rhythm.

Table 3

Impact of the drop-and-hook model on the sustainability and continuity of interregional transportation in the USA (2018–2025)

Indicator	Traditional transportation model	Drop-and-hook model	Effect
Share of completed trips during delays at warehouses, %	63.4	82.5	+19,1 p.p.
Average time to restore normal schedule after peak load, h	48	29	−39,6%
Share of delayed deliveries during critical weather conditions, %	28.6	11.8	−58,7%
Time loss due to downtime at terminals, h/thousand km	17.9	6.4	−64,2%
Level of continuity of logistics flow, %	71.2	89.6	+18,4 p.p.

Source: author's own calculations given [20–23]

The data in table 3 show that drop-and-hook significantly increases supply chain resilience. It is shown that, as a result of implementing the model, time losses were reduced by 63.8%, canceled flights by 68.3%, and the percentage of cargo delayed by more than 24 hours was reduced almost threefold [20].

Research into the role of the drop-and-hook model in ensuring the resilience and continuity of interregional supply chains in the face of risks and crises has shown that its use significantly reduces the logistics system's sensitivity to external shocks. In particular, when modeling situations of delays in warehouses in the central logistics hubs of the USA (Chicago and Memphis), it was found that the use of drop-and-hook allows for saving up to 82.5% of planned flights even under conditions of violation of loading schedules, while in the traditional model, this figure does not exceed 63.4%.

In cases of sharp demand growth, such as during the pre-Christmas peak period, when the volume of transportation in the Walmart and Amazon networks increases by more than 35%, the use of drop-and-hook provides a more even

distribution of transport resources between regions. According to the results of the scenario analysis, the average time to restore the normal rhythm of deliveries after the peak load decreased from 48 to 29 hours, indicating an increase in the system's adaptability [21–22].

Separately, it was found that in crisis situations associated with weather restrictions (hurricanes in the southern states of the USA), the model enables minimizing tractor downtime by pre-preparing trailers at alternative hubs. The share of delayed deliveries in such conditions was 11.8% in the drop-and-hook system versus 28.6% in the traditional transportation scheme, which confirms its greater resistance to logistical failures [23].

The results obtained on the impact of the drop-and-hook model on the efficiency and sustainability of logistics systems are consistent with the findings of D. Wang et al., who found that the separation of tractors and trailers in container transportation allows for reduced operational delays and increased use of transport resources through route optimization and reduced downtime [24]. The analysis also showed a decrease in downtime and an increase in completed trips, confirming the effectiveness of this model in conditions of intensive transportation.

The obtained data partially differ from the provisions of A. Aloui et al. note that increasing the resilience of logistics networks in crisis conditions is primarily achieved through route diversification and capacity reservation, rather than through changes at the operational level of vehicles [25]. At the same time, it was found that the drop-and-hook operational model significantly reduces the time required to restore logistics flows after failures, thereby expanding traditional approaches to understanding and assessing the resilience of logistics systems.

The differences between the results are explained by the fact that in the mentioned works the main attention is paid to the macro level of supply chain management, whereas in this study the emphasis is on the micro-operational level

of transport processes, in particular the interaction between tractors and trailers within the hub system.

Thus, the results of the presented analysis indicate that the drop-and-hook model increases the continuity of supply chains by reducing dependence on the time of cargo processing in warehouses and ensures faster restoration of logistics flows after crisis impacts, which confirms its role as one of the key tools for increasing the resilience of modern interregional transport systems.

Conclusions. Analysis of the organizational and economic features of the drop-and-hook model in the USA road transport system demonstrated that its implementation reduces vehicle downtime, increases tractor and trailer turnover, and increases driver productivity. It was found that the model's effectiveness depends on the availability of developed infrastructure, clear planning of transportation schedules, and the readiness of cargo for processing.

An assessment of the impact of the drop-and-hook model on key logistics performance indicators, based on the analysis of statistical data, showed that after its implementation, the average cost per trip decreased by 16%, the idle time of tractors decreased by 65.6%, and the number of trips per vehicle increased by 33.3%. In addition, delivery reliability increased by 7.8%, indicating improved operational efficiency in interregional supply chains.

A study of the role of the drop-and-hook model in increasing the resilience of logistics systems in crisis conditions revealed that its application allows reducing the share of delayed deliveries during adverse weather conditions and reducing the time to restore the normal transportation schedule, and an increase in the level of continuity of the logistics flow indicates the model's ability to increase the operational resilience of interregional supply chains.

It has been established that the economic efficiency of the drop-and-hook model manifests itself through cost and time optimization and through increased

flexibility and adaptability of transport processes to changes in demand and environmental conditions, which justifies its use in modern USA logistics systems.

Prospects for further research lie in adapting the drop-and-hook model to other modes of transport and markets with excellent infrastructure, as well as in modeling its impact on integrated multimodal supply chains to increase global logistics sustainability.

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