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THE RESEARCH OF OPTIMAL DELIVERY TECHNOLOGY OF CONFECTIONERY IN A SUPPLY CHAIN

This research is dedicated to the issue of choosing the optimal technology of each participant in a supply chain, namely the transportation mode choice (road or rail) during the trunk traffic, the choice of optimal technology of loading and unloading machines of wholesaler (mechanized or automated). The optimal delivery technology of confectionery while shipping in Ukraine of the chain participants and the chain on the whole have been determined.

Keywords: *transport mode, delivery, distribution centre, supply chain.*

Introduction

Major manufacturing companies are faced with two main stages in the commodity delivery: delivery from the manufacturer to the distribution centre, delivery from the distribution centre to the retail network. At the same time, as the analysis of the operating of Ukrainian major manufacturing enterprises shows, these stages of delivery are implemented independently of each other, by different transport departments. For example, delivery from the manufacturer to the distribution centre is carried out by the main transport department of the enterprise, and the distributor is engaged in the process of delivery to the retail network. Such schemes of organization of a transport process can hide possible variants of delivery process optimization of products. Therefore, the paper investigates the joint transport process of delivery of products from the manufacturer to the retail network, taking into account the work of loading and unloading mechanisms at the distribution centre, and to choose the transport mode while transporting cargo in highway. An interesting example for this study is the process of delivery of confectionery from the manufacturer to the retail network, as the transportation of this group of goods requires increased paying attention and some specific conditions of transportation, in particular, strict adherence to the terms of transportation, conditions of carriage and loading and unloading works to ensure the integrity of the cargo.

Literature review

Many of the studies are dedicated to the optimization of a logistics chain. Having analyzed the existing literature sources, it was possible to identify the main directions of the study of logistics chains: the study of transport processes [1, 2, 3-6], the study of the distribution phase [7, 8], the study of inventory management processes [9-11] and the study of logistics chain as a whole [12-19].

In these source [18] the logistics chain efficiency, the main participants of which is transport, broker, retailer, is determined. In this paper the laws of the influence of the transport participant characteristics and warehouse characteristics on the efficiency of the logistics chain are highlighted. However, less attention is paid to the choice of the optimal transport technology in a logistics chain. In study [7] a framework for designing the distribution network in a supply chain is investigated. In study [8] spatial-temporal logistics interaction model integrated with Markov chain that allows to forecast time-varying logistic distribution flows for a three-layer supply chain framework is determined. In study [9] a nonlinear programming model by considering fixed transhipment cost, that allows to reduce the channel-wide cost is proposed. Integrated inventory model consists of a single vendor and multiple buyers with warehouse capacity sharing via transhipment. In paper [12] research evaluates how vendor managed inventory affects a supply channel. This research is highlighted the necessity of using fully integrated supply chain for buyer and supplier based on short-run and long-run benefits. The paper [10] examines the total cost benefits that can be achieved by suppliers and warehouses through the increased global visibility provided by an integrated system.

The main criteria of logistics chain efficiency are: logistics costs [10, 12], transhipment cost [9], travel time, cost, [1], reference price [14], prices and quality levels [11], price and distance [16], transportation cost discounts [3]. The main methodological basis of studying the problems consist of: modelling, expert methods, binary logit and probit models, model based on the analytic hierarchy process.

The purpose of this paper is to choose the optimal delivery technology in a logistics chain, namely the choice of the transport mode (road or rail) during the transportation in highway, the choice of the optimum technology of work of loading and unloading mechanisms at the distribution centre (semi-mechanized, mechanized or automated).

Research

In the first stage of the study, a system simulating of the delivery process of confectionery products from the manufacturer to the retail network was carried out. The interrelations between participants of the chain, problem issues, limits of the logistics chain have been defined. Let's consider the logistics chain at the different stages of shipping, in particular, the technological interaction of the operation of trunk transport, loading and unloading mechanisms. Choosing the best technology for the delivery process in the logistics chain involves (1) choosing the transport mode (road or rail) while trunk transportation, (2) choosing the optimal technology for handling the loading and unloading mechanisms at the distribution centre (semi-mechanized, mechanized or automated), Fig. 1.

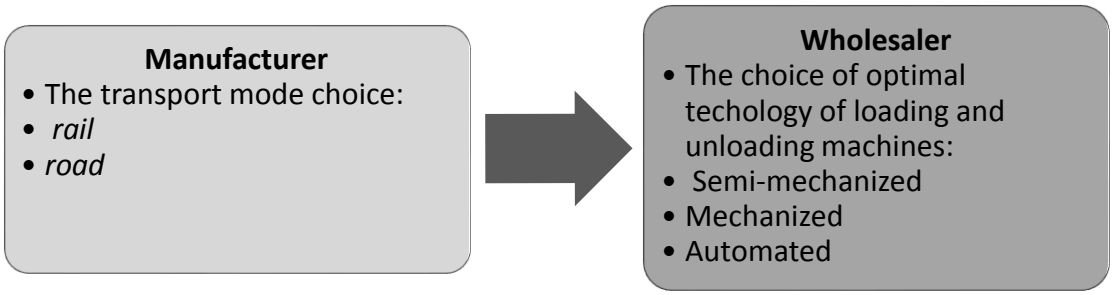

Fig. 1. Logistics chain participants

The mathematical model of the logistics chain has been developed. The mathematical model of an optimization problem is characterized by the following formula:

$$C_{sys} = \min \left\{ C_{trunk}, C_{Load} \right\}, \quad (1)$$

Where C_{trunk} is delivery costs for trunk transportation from the manufacturer to the distribution center, UAH / year; C_{Load} is the costs of the operating of the loading and unloading mechanisms at the distribution center for the year, UAH / year;

It is important to study using the rail in two situations: when the distribution centre owns their own rail siding and the one when they don't, Fig. 2. In this case the manufacturer has their own rail siding. The palletised confectionary is moving into insulated vehicles in intercity traffic. This way, moving freight by rail is possible in two ways: 1) manufacturer – rail – distribution centre, 2) manufacturer – rail – truck – distribution centre. In order to compare using road and rail transport it is necessary to view the transportation process starting with the fulfilment of an order the length of time from the moment when the shipment order comes through until the shipment is dispatched. This is due to the fact that the time used to fulfil the order differs depending on whether road or rail transport is used. In Ukraine it takes 3 to 10 days to fulfil an order when using the rail, and up to 3 days when it comes to road transportation. In addition, the quantity of cargo impacts the time of terminal operations including receiving, sorting, dispatching the freight at a marshalling yard. For instance, it can take from 1 to 5 days for a train to de loaded [20].

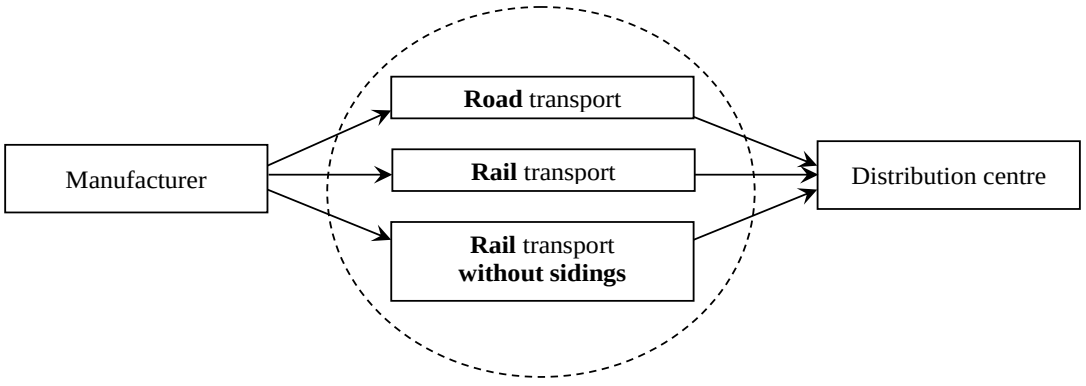

Fig. 2. Shipping of confectionery products in supply chain

Therefore, using the rail significantly increases transportation time, compared to road transportation, which, in its turn, influences the immobilization of funds while the shipment is being carried out. After the order is formed, the freight is dispatched from the warehouse and loaded onto the vehicle or wagon. After the freight is loaded, it is moved to its destination by road or rail. When the freight arrives, it is offloaded and received at the distribution centre. The technological process while loading and unloading the freight while using the rail is more time-consuming than the one used in road transportation.

Terminal operations include receiving and dispatching the freight, creating the paperwork for transporting the freight, delivering the wagons to be loaded and offloaded. If the transportation is done with the help of a different scheme and road transport needs to be used as auxiliary transport mode, the number of technological operations related to loading and unloading of the increases. All of these operations clearly increase the time that it takes for the freight to be delivered by rail transport. However, the rail charges for transporting 1 ton of freight decreases as the distance of delivery grows longer. Therefore, further study of the road and rail freight transportation is required.

The criterion of the effectiveness of transport mode choice is the total logistics costs:

$$C_{LC} = \min\{C_{rail}, C_{road}\}, \quad (2)$$

where C_{rail} is total logistics costs while transporting cargo by rail, UAH per year; C_{road} is total logistics costs while transporting cargo by road, UAH per year.Total logistics costs while transporting cargo by road or rail are characterized by the following formula:

$$C_{road} = C_{pre} + C_{trans} + C_{rec} + C_{im}, \quad (3)$$

where C_{pre} is cost for the preparation of goods for dispatch, UAH per year; C_{trans} is transportation costs, UAH per year; C_{rec} is costs for receiving of cargo, UAH per year; C_{im} is the immobilization of funds, UAH per year.

The key indicator of the assessment of the capacity of the logistics chain is the amount of material flow that passes through the chain over a certain period of time. Proceeding from this, this research are invited to analyze the work of the logistics chain, depending on the different amount of material flow. Thus, the analysis of the confectionery enterprises, made it possible to determine the appropriate variation in amount of material flow in a year. Thus, the results of calculations of total logistics costs during the shipping from the manufacturer to the distribution center by road and rail is presented in Tab. 1, Fig. 3.

Table 1

Total logistics costs while transporting cargo by road or rail with respect to amount of cargo

Costs	Amount of goods, ton per year								
	10000			5000			100000		
	Road	Rail	Rail without sidings	Road	Rail	Rail without sidings	Road	Rail	Rail without sidings
For preparation of dispatch	1042486	1042486	1042486	521243	521243	521243	194444515	194444515	194444515
Transportation	3832996	2638802	2999602	1780881	1319554	1500354	46220366	26395767	30003767
Receiving of cargo	183475	184910	184910	91738	92455	92455	1834750	1849100	1849100
The immobilization of funds	394521	2367123	2367123	61644	1183562	1183562	11835616	23671233	23671233
Total logistics costs	5453477	6233321	6594121	2455505	3116814	3297614	254335248	246360615	249968615

We can observe that the using road transport during transportation is efficiently if cargo amount is from 5,000 and 10,000 tons per year, but if amount of cargo is increased, it is rational to use rail transport. The bigger the cargo amount, the larger the difference between transport costs of road and rail delivery.

One of the possible options for choosing the technology of the distribution centre operation is the choice of rational loading and unloading facilities. The work of these mechanisms, namely, their capacity and the time of loading and unloading affects the whole cycle of delivery. The paper proposes to investigate the process of loading and unloading operations in the distribution centre during the shipping of confectionery products in a logistics chain. Thus, the issue of choosing the rational technology during loading and unloading operations depends on the method of organisation of this operations and the determination of technological change points, for example, the replacement of mechanized to automated technologies.

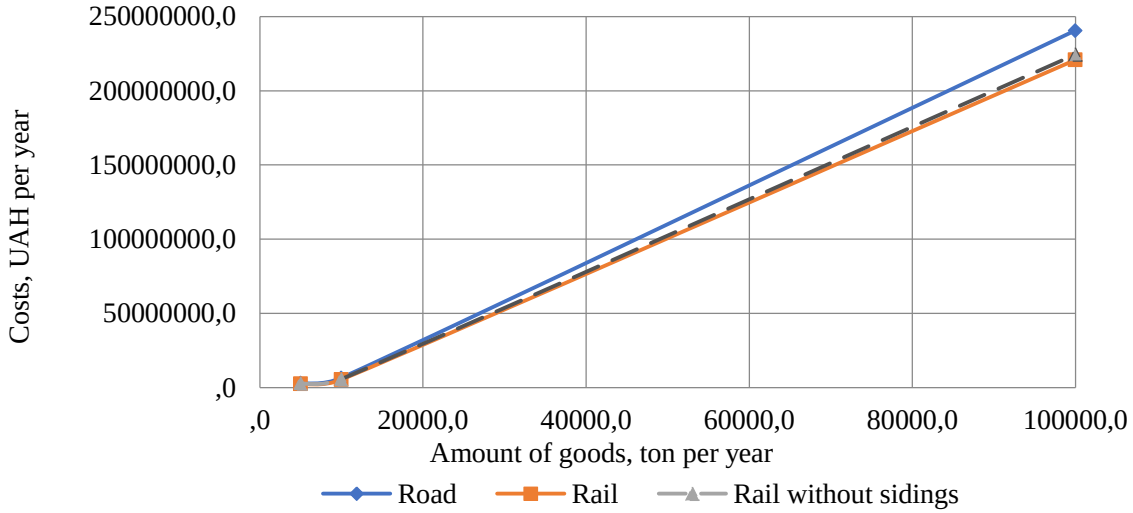

Fig. 3. Total logistics costs while transporting cargo by road or rail with respect to amount of cargo

There is not the best (absolutely) in terms of technology costs, but there are the best technologies for a certain amount of production. So, in logistics, it is expedient to consider the types of loading and unloading technologies depending on the use of manual labour, that is: manual (1), semi- mechanized (2), mechanized (3), automated (4). On the one hand, such a sequence of technologies is organized by the growth of capital costs, that is, capital costs of manual technology (1) < capital costs of semi-mechanized (2) < capital costs of mechanized (3) < capital costs of automated (4). On the other hand, decrease of variable costs: variable costs of manual technology (1) > variable costs of semi-mechanized (2) > variable costs of mechanized (3) < variable costs automated (4) [21].

The manual method involves loading or unloading without the using of mechanisms. The semi-mechanized method involves the using of manual labour and mechanisms (hand stacker etc.). The mechanized method involves performing loading and unloading operations using the mechanisms that a individual manages. The automated technology involves loading and unloading without direct human involvement in the process.

With a comprehensive approach to the definition of technological scenarios of the warehouse designer has to calculate in detail and compare a large number of options (sometimes more than 20), which significantly increases the time of design work and increases them. Taking into account the fact that some of the calculations for assessing the life cycle of technology and the definition of technology-substitute are carried out on the 5-year forecast horizon, it is necessary to plan accurately the economic unit of output data such as the cost of equipment, staff salary, discount rates and inflation rates [22]. The proposed loading or unloading mechanism are presented in Fig. 4.

Semi-mechanized	**Mechanized**	**Automated**
HSA 1516 hand stacker	Toyota 7FDF25-2	Rocla AGV
		

Fig. 4. The loading and unloading mechanism

The optimal criterion in the case of choosing the best technology for loading and unloading operations is the reduced costs, in a year. The reduced costs is characterized by the following formula:

$$З_г = З_м + E_н \cdot (x_и \cdot к_м), \quad (4)$$

where $З_м$ is costs for the operation of machines,

UAH per year; $к_м$ is book value of the unit of the loading and unloading mechanism, UAH; $E_н$ is the efficiency coefficient of capital investments.

Costs for the operation of machines is characterized by the following formula:

$$З_м = (З_{чр} + З_{вп}) \cdot x_м \cdot D_w, \quad (5)$$

where $З_{чр}$ and $З_{вп}$ are costs for the time of idle machines during the day, UAH; $x_м$ is number of loading and unloading mechanism; D_w is working days in a year, days.

The costs for one loading and unloading mechanism during the period of network and in-line idle time are determined depending on the cost of machine-hours, according to the network and in-line idle mechanism (UAH / hour), the duration of the loading and unloading station during the day (h), the coefficient of use of working time mechanism, time according to the network. The number of loading and unloading mechanism is determined depending on the annual amount of cargo (ton per year), the use fleet coefficient, the operational efficiency of the mechanism (ton per year). Operating performance of machines of cyclic action is determined by the duration of the working cycle, depending on the actual weight of the cargo moving in one working cycle (ton), the coefficient of use of working time, the duration of the working cycle, second. This indicator is determined by the formula:

$$T_ц = \varphi \cdot \sum_{i=1}^{n_{оп}} t_i + n_{оп} \cdot t_{оп}, \quad (6)$$

where φ is the combination of operations during the working day; t_i is time period of operation, second; $t_{оп}$ is time for decision-making by the operator (driver) and switching control units for one operation, second; $n_{оп}$ is number of switching over the cycle. The required number of mechanisms for daily cargo amount is determined depending on the daily cargo volume, capacity and working time of the mechanism.

The results of calculations are summarized in Table 2.

Table 2

The costs of loading and unloading operations

Indicator	Amount of goods, ton per year								
	5000			10000			100000		
	Semi-mecha-nized	Mecha-nized	Auto-mated	Semi-mecha-nized	Mecha-nized	Auto-mated	Semi-mecha-nized	Mecha-nized	Auto-mated
Number	1	1	1	2	1	1	14	5	1
Costs for the time of work during the day, UAH	2393	5345	24209	2393	5345	24209	2393	5345	24209
Costs for the time of idle machines during the day, UAH	203	988	2547	203	988	2547	203	988	2547
Costs for the operation of machines, UAH per year	778846	1899930	8026771	1557693	1899930	8026771	10903850	9499649	8026771
Reduced costs, UAH per year	782646	1918430	8169771	1565293	1918430	8169771	11542250	10461649	8598771

A comparative analysis was carried out with the help of graphical interpretation and technological change points was established, Fig. 5. Having analysed the results, we can conclude that in the production of 5 to 33 thousand tons it is expedient to use semi-mechanized loading and unloading mechanism; from 33 to 80 thousand tons it is expedient to use mechanized technology; from 80 to 100 thousand tons it is expedient to use automated technology.

Thus, given the different cargo amount, the optimal number of loading and unloading mechanism, costs for the time of work during the day, costs for the time of idle machines during the day, costs for the operation of machines and reduced costs have been determined.

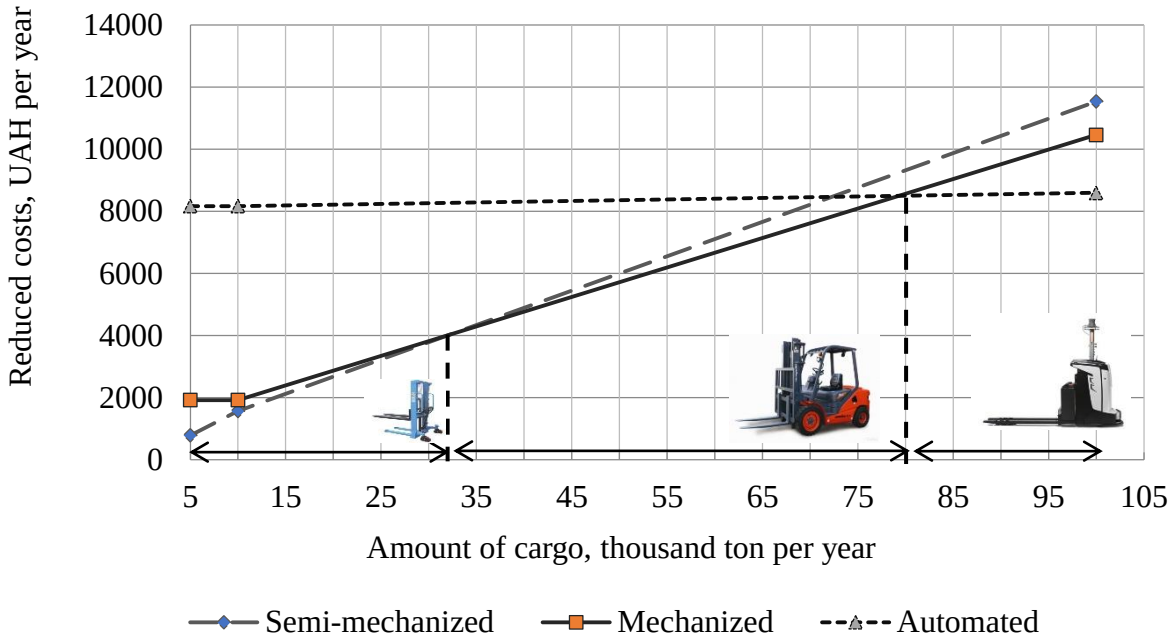

Fig. 5. Reduced costs with respect to amount of cargo

The above results of the selection of transport mode in trunk shipping and loading and unloading technology allows to determine the optimal delivery technology of confectionery in a supply chain during shipping cargo in Ukraine by the criterion of minimum total logistics costs, formula (1). The results are presented in the Table 3.

Table 3

Optimal delivery technology of confectionery in a supply chain

Cargo amount, thousand ton per year	Loading and unloading mechanism	Transport mode	Total logistics costs, UAH
5 – 33	Semi-mechanized	road	3581233
33 – 80	Mechanized	road	5779452
80 – 100	Automated	rail	39149156

Thus, different possible variants of delivery technology of confectionery in a supply chain were calculated, as a result, we received optimal technology for each participant and for the supply chain as a whole with respect to different cargo amount.

Conclusions

It can be concluded, that depending on the annual cargo amount, the optimal delivery technology of confectionery products is different. Thus, if annual cargo amount is from 5000 to 33 000 ton, the optimal technology for loading and unloading operations is semi-mechanized (road delivery cargo from manufacturer to distribution centre), if annual cargo amount is from 33000 to 80 000 ton, the optimal technology for loading and unloading is mechanized (road trunk delivery), if annual cargo amount is from 80 000 to 100 000 ton, the optimal technology for loading and unloading is automated (rail trunk delivery).

In the further study it is necessary to study fully delivery process by adding to the model indicator of shipping cargo from distribution centre to retailer network, that can change obtained results due to limits of retailer requirements.

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ВИБІР ОПТИМАЛЬНОЇ ТЕХНОЛОГІЇ ДОСТАВКИ КОНДИТЕРСЬКИХ ВИРОБІВ У ЛАНЦЮГА ПОСТАЧАННЯ

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Великі корпорації, виробничі компанії після виготовлення власної продукції стикаються з проблемою доставки її споживачам. На цьому етапі існує велика різноманітність варіантів взаємодії різних технологій виробника, оптовика (дистриб'ютора) та роздрібного продавця. Багато досліджень присвячено питанню постачання в мережах постачання окремих постачальників чи постачальників. У той же час значне значення набуває крос-кросове узгодження процесу доставки, включаючи технологічну взаємодію магістрального транспорту, складських операцій та міського вантажного транспорту. Це дослідження присвячено питанням вибору оптимальної технології кожного учасника в ланцюгу постачання, зокрема вибору режиму перевезення (автомобільну або залізничну) під час магістральних перевезень, вибору оптимальної технології навантажувальних та розвантажувальних механізмів. Для вирішення цього питання запропоновано математичну модель роботи ланцюга постачання, критерій ефективності моделі - загальні витрати ланцюга постачання. Методи в дослідженні – методи системного аналізу, математичного моделювання, регресійного аналізу. Визначено оптимальну технологію доставки кондитерських виробів під час доставки кондитерських виробів в Україні. Зокрема встановлено оптимальний тип навантажувально -розвантажувальних механізмів залежно від річного обсягу вантажу в дистрибуційному центрі. Так, залежно від річного вантажообігу оптимальна технологія доставки кондитерських виробів відрізняється. Таким чином, якщо річна сума вантажу становить від 5000 до 33 000 тон, оптимальна технологія навантаження та розвантаження – напівмеханізована, якщо річна сума вантажу становить від 33000 до 80 000 тон – механізована; якщо річний вантаж становить від 80 000 до 100 000 тон, оптимізована технологія – автоматизована. Надано рекомендації щодо прийняття рішень стосовно вибору технології доставки кондитерських виробів у магістральному сполученні.

Ключові слова: *вибір виду транспорту, ланцюг постачання, навантажувально-розвантажувальні роботи.*