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ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК РЕСПУБЛИКИ КАЗАХСТАН»
ЧФ «Халық»

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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

ЧФ «ХАЛЫҚ»

В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением,
Благотворительный Фонд «Халык»!

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CONSTRUCTION OF MATHEMATICAL MODEL OF TECHNOLOGICAL INTERACTION PROCESSES BETWEEN SEA AND REAR CONTAINER TERMINALS

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Abstract. Currently, an important problem for transport is the organization of logistics systems of transportation management with the interaction of different modes of transport, as well as the development of transport infrastructure with the construction of terminal complexes and ports, providing multimodal transport and intermodal technology. The research in this article is aimed at solving these problematic issues. The issues of technological interaction between marine and rear container terminals in the planning of land-based cargo distribution networks are considered. The main task of the study is to obtain the necessary information about the level of technological interaction between marine and rear container terminals in a two-link system and the parameters of terminal warehouses and to analyze the development of the mechanism of cargo volume formation in the warehouse of the marine and rear container terminal. Using analytical methods, the formula for calculating the maximum capacity of terminal warehouses was derived and the values of basic capacity of sea and rear terminal warehouses for export and import directions were determined. We used methods of mathematical modeling to build a simulation model of a two-link system: a sea terminal - a rear terminal, which allows us to estimate the impact of uneven arrival of vehicles on the required storage capacity of sea and rear terminals. Under the territorial restrictions of the port, this allows to minimize the port storage area, the transshipment equipment fleet and provides for rational distribution of the transshipment equipment workload with a proportional response to changes in the size and frequency of the required consignment arrivals at the terminal. The results of the study can be used for optimal planning of sea transport and seaport infrastructure facilities.

Keywords: containers, seaports, cargo front, back terminals, planning, modeling, cargo distribution lines, cargo flow, dry port

© А.У. Табылов[1*], О.Г. Киквидзе[2], А.З. Букаева[1], Н.Б. Суйеуова[1], А.А. Юсупов[1], 2024

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ТЕҢІЗ ЖӘНЕ АРТҚЫ КОНТЕЙНЕРЛІК ТЕРМИНАЛДАРДЫҢ ТЕХНОЛОГИЯЛЫҚ ӨЗАРА ІС ҚИМЫЛ ПРОЦЕСТЕРІНІҢ МАТЕМАТИКАЛЫҚ МОДЕЛІН ҚҰРУ

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Аннотация. Қазіргі уақытта көліктің маңызды проблемасы көліктің әртүрлі түрлерінің өзара іс-қимылымен тасымалдауды басқарудың логистикалық жүйелерін ұйымдастыру, сондай-ақ мультимодальды тасымалдауды және интермодальдық технологияларды қамтамасыз ететін терминалдық кешендер мен порттардың құрылысымен көлік инфрақұрылымын дамыту болып табылады. Осы мақаладағы зерттеу осы проблемалық мәселелерді шешуге бағытталған. Жерүсті жүк тарату желілерінің жұмысын жоспарлау шеңберінде Теңіз және тыл контейнерлік терминалдарының технологиялық өзара іс-қимыл мәселелері қаралды. Зерттеудің негізгі міндеті-екі буынды жүйеде және терминал қоймаларының параметрлерінде теңіз және артқы контейнер терминалдарының технологиялық өзара іс-қимылының деңгейі туралы қажетті мәліметтер алу және теңіз және артқы контейнер терминалының қоймасында жүк көлемін қалыптастыру механизмін әзірлеуді талдау. Аналитикалық әдістермен терминалдар қоймаларының максималды сыйымдылығын есептеу формуласы шығарылды және экспорттық және импорттық бағыттар үшін теңіз және артқы терминалдар қоймаларының базалық сыйымдылығының мәндері анықталды. Екі буынды жүйенің имитациялық моделін құру үшін математикалық модельдеу әдістері қолданылды: теңіз терминалы-артқы терминал, бұл теңіз және артқы терминалдар қоймаларының қажетті көлемінің мөлшеріне көлік құралдарының біркелкі келмеуінің әсерін бағалауға мүмкіндік береді. Порттың аумақтық шектеулері жағдайында бұл портты сақтау алаңдарын, қайта тиеу жабдықтарының паркін азайтуға мүмкіндік береді және терминалға талап етілетін партиялардың түсу мөлшері мен жиілігінің өзгеруіне пропорционалды жауап бере отырып, қайта тиеу техникасының жұмыс көлемін ұтымды бөлуді қамтамасыз етеді. Зерттеу нәтижелерін теңіз көлігі мен теңіз портының инфрақұрылымдық нысандарының жұмысын оңтайлы жоспарлау үшін пайдалануға болады.

Түйін сөздер: контейнерлер, теңіз порттары, жүк фронты, артқы терминалдар, жоспарлау, модельдеу, жүктерді тарату желілері, жүк ағыны, құрғақ порт

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ПОСТРОЕНИЕ МАТЕМАТИЧЕСКОЙ МОДЕЛИ ПРОЦЕССОВ ТЕХНОЛОГИЧЕСКОГО ВЗАИМОДЕЙСТВИЯ МОРСКИХ И ТЫЛОВЫХ КОНТЕЙНЕРНЫХ ТЕРМИНАЛОВ

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Аннотация. Важной проблемой для транспорта в настоящее время является организация логистических систем управления перевозками с взаимодействием различных видов транспорта, а также развитие транспортной инфраструктуры со строительством терминальных комплексов и портов, обеспечивающих мультимодальные перевозки и интермодальные технологии. Исследование в данной статье направлено на решение этих проблемных вопросов. Рассмотрены вопросы технологического взаимодействия морских и тыловых контейнерных терминалов в рамках планирования работы наземных грузораспределительных сетей. Основная задача исследования — получение необходимых сведений об уровне технологического взаимодействия морского и тылового контейнерных терминалов в двухзвенной системе и параметрах складов терминалов и анализ выработки механизма образования объема груза на складе морского и тылового контейнерного терминала. Аналитическими методами выведена формула для вычисления максимальной емкости складов терминалов и определены значения базовой вместимости складов морского и тылового терминалов для экспортного и импортного направлений. Использованы методы математического моделирования для построения имитационной модели двухзвенной системы: морской терминал – тыловой терминал, позволяющей оценить влияние неравномерности поступления транспортных средств на величину необходимого объема складов морского и тылового терминалов. В условиях территориальных ограничений порта это позволяет минимизировать портовые складские площади хранения, парк перегрузочного оборудования и обеспечивает рациональное распределение объема работы перегрузочной техники с соразмерным реагированием на изменения размеров и частоты поступлений требуемых партий на терминал. Результаты исследования могут быть использованы для оптимального планирования работы морского транспорта и инфраструктурных объектов морского порта.

Ключевые слова: контейнеры, морские порты, грузовой фронт, задние терминалы, планирование, моделирование, линии распределения грузов, грузопоток, сухой порт

Introduction

Recently, the issues of technological interaction between seaports and rear terminals have been given active attention in the multimodal transportation system, the number of scientific works on this subject is constantly growing (Aravindan et al., 2016). However, in spite of the fact that some basic formulas and methodologies are subjected to numerous changes, the task of optimizing technological interaction and warehouse capacity in the two-link sea port-dry port system remains unsolved.

In this regard, finding a solution and developing appropriate recommendations in general terms, taking into account the increasing competition between transport infrastructure facilities, is an urgent task. Sea front and rear container terminals are united by a similar functional structure and purpose (transfer of cargo between modes of transport, coordination of cargo flows, commercial storage, logistic completion). Nevertheless, each type of terminal has a priority functional profile, which determines the peculiarities of their structure (Bobryshev et al., 2013; Kuznecov et al., 2013).

Materials and methods

Consider a sea container terminal as the simplest functional element, serving to connect the inbound and outbound flows through it (Fig. 1).

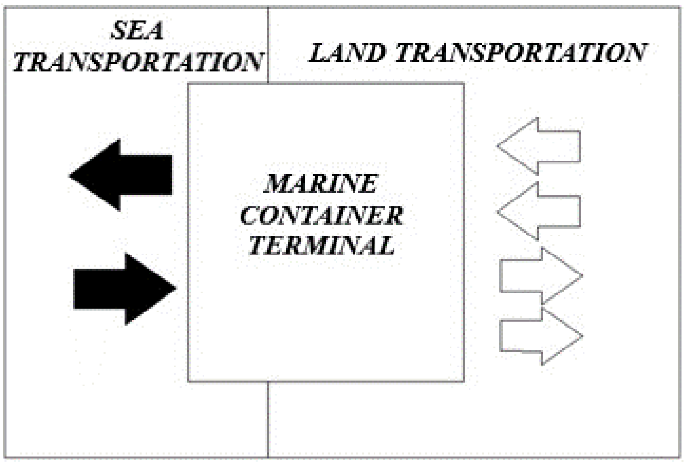

Fig.1. Container terminal as a logistics element

The export cargo flow Q_{exp}, arriving to the port by land transport and processed at the land freight front of the port (hereinafter - Q_{CF}), we denote as $Q_{QCF}(t)$, and leaving it by sea and processed at the sea freight front of the port (hereinafter - SCF) as $Q_{SCF}(t)$. The value of the volume of cargo stored in the terminal warehouse at the moment of time is obtained by the integrated expression:

$$E_{wareh.}(t) = \int_0^t [Q_{QCF}(t) - Q_{SCF}(t)]dt + E_0 \quad (1)$$

where: E_0 — an arbitrary constant, defined as the initial stock of cargo in the warehouse.

The nature of this relationship is shown in Fig.2. Cargo delivery to the port is usually carried out both by road transport (small cargo lots) and by railroad (medium cargo lots), while cargo exportation is carried out by large shiploads. All together, this leads to characteristic changes in storage volumes. Uneven import and export leads to excess or shortage of cargo in the warehouse of the sea terminal (Kuznecov, 2008; Kuznecov et al., 2010). In this connection, it is necessary to store cargo in the port in the volume exceeding the size of one ship's batch, and it is necessary to have the possibility to store excess stock at the terminal warehouse, arising in case of delay of export due to non-arrival of a vehicle (vessel), as well as to accumulate "safety" stock, intended for loading of a vessel arriving earlier than planned.

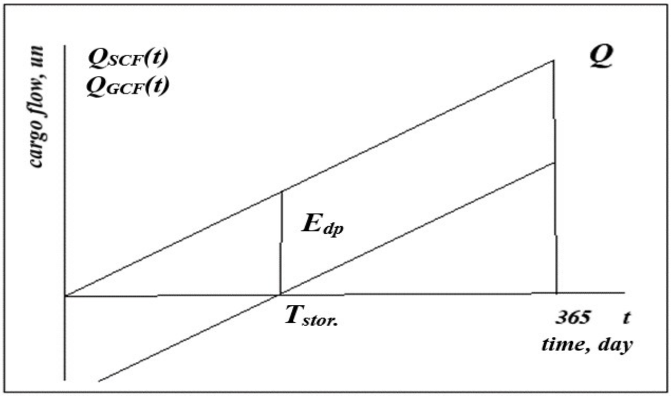

Fig.2. Estimation of storage volume in the port warehouse

Finally, at annual cargo flow *Q* the need to store cargo at the terminal for some period of time Txr (according to the requirements of state authorities or on behalf of the client) leads to the fact that there is an additional permanent stock E_0 in the warehouse.

The volume of cargo in the warehouse due to storage *T* is equal to the vertical distance between the average lines of entry and exit:

$$E_0 = \frac{T_{keep.} * Q_{ann.}}{365} \quad (2)$$

Combining expressions (1) and (2), you can get an expression for the volume of cargo in the warehouse:

$$E_{wareh.}(t) = \int_0^t [Q_{QCF}(t) - Q_{SCF}(t)]dt + \frac{T_{keep.} * Q_{ann.}}{365} \quad (3)$$

The introduction of another element in the chain of transportation - a dry port - allows the rational distribution of functions between the marine and rear terminals for the storage of excess inventory arising in case of delayed exports due to the non-arrival of a vehicle (vessel), as well as the accumulation of safety stock, designed to load the vessel that arrived earlier than planned (Junfang Cao, 2022; Kuznecov et al., 2011).

In the system of sea-port-dry port interaction, apart from the onshore cargo flow $Q_{QCF}(t)$ entering the system (directly to the dry port) and the outgoing marine cargo flow $Q_{SCF}(t)$, there is a cargo flow from the dry port to the sea port - $Q_{DP}(t)$. The two-link system allows minimizing the storage volume requirements in the most scarce coastal areas by transferring commercial storage to rear areas, and also provides an opportunity to partially transfer to the dry port the function of buffer of cargo inlet and outtake irregularities. The two-link system allows these functions to be divided between the seaport terminal and the rear terminal, leaving the former solely to handle seagoing vessels (Kitikov et al., 2013; Fetisov et al., 2011; Schruben, 1983).

The flow from the sea terminal to the dry port can be in full control of the terminal operator (if the access roads are used for its implementation) or have some external restrictions on the capacity of vehicles and the schedule of their movement (if the common use tracks of the railway operator are used). All three flows are characterized by the cargo flow continuity ratio:

$$\int_0^{365} Q_{SCF}\, dt = \int_0^{365} Q_{QCF}\, dt = \int_0^{365} Q_{DP}\, dt \qquad (4)$$

The difference in size and inconsistency in the schedules of incoming and outgoing element cargo shipments change the nature of their effect on the size of the warehouse. If for export shipments the export from the sea terminal in the two-link system remains unchanged, then the entry of export cargo to the sea terminal is now carried out by the intermediate cargo flow $Q_{DP}(t)$. The cargo flow at the inlet of the land terminal $Q_{QCF}(t)$ remains unchanged, and the export from it is characterized by the intermediate flow $Q_{DP}(t)$.

Thus, the absolute value of cargo volume in the warehouse of the seaport is determined by the expression:

$$E_{mar.wareh.}(t) = \int_0^t [Q_{DP}(t) - Q_{SCF}(t)]dt + \frac{T_{keep.} * Q_{ann.}}{365} \qquad (5)$$

while the volume value of the cargo volume in the dry port warehouse can be represented as:

$$E_{qroun.wareh.}(t) = \int_0^t \left[Q_{QCF}(t) - Q_{DP}(t)\right]dt + \frac{T_{keep.} * Q_{ann.}}{365} \qquad (6)$$

If the intermediate Q_{DP} flow is under the control of the terminal operator and has no restrictions on the size and frequency of feeds, any task can be solved by changing it - from complete elimination of storage at the sea terminal to complete elimination of storage at the rear terminal. In order to develop recommendations on the formation of internal cargo flow and the distribution of functions between the links of the transport chain, the following conditions must be observed:

- reduction of space required for the organization of storage in the most expensive area (reduction of capital costs);

- reduction in the fleet and evenly distributed intensity of the required transshipment equipment at the sea terminal;
- possibility of adequate response to changes in the size of the required batches.

Due to the fact that the cost of storing cargo at a container terminal depends on the specific costs of the terminal owner to maintain the infrastructure, it is reasonable to proceed further to determine the capacity of the Emar.wareh marine terminal warehouse and the "dry port" warehouse Eqroun.wareh.

Results

Having analyzed the curve shown in Fig. 3 curve of dynamic component of seaport warehouse volume for export cargo flow, we can see that at regular import and export the maximum values of cargo volume in the warehouse do not exceed the volume of ship's shipment *V*.

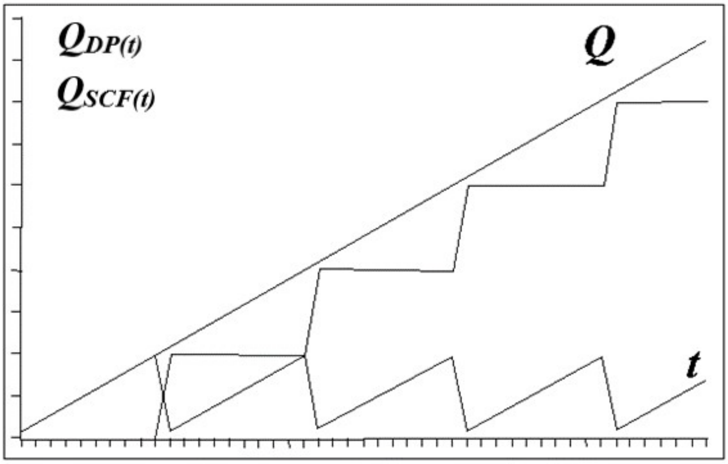

Fig.3. The dynamic component of the volume of the seaport warehouse

Consequently, the following expression gives a maximum estimate of the capacity of a seaport container terminal:

$$E \leq V + \frac{Q_{ann.} T_{keep.}}{365} = V + \frac{NVT_{keep.}}{NT_{ship}} = V\left(\frac{T_{keep.}}{T_{ship}} + 1\right) \qquad (7)$$

In this case full transfer of the commercial storage function to the dry port, i.e. $T_{keep.} = 0$, will reduce the maximum capacity of the sea container terminal and give the following expression:

$$E \leq V + \frac{Q_{ann.} T_{keep.}}{365} = V \qquad (8)$$

For a rear container terminal the situation will be similar. When importing by rail the incoming cargo flow $Q_{QCF}(t)$ to the terminal will be characterized by the volume of cargo delivered by expedited container trains (hereinafter - ACT) - V_{ACT}, while exporting cargo from the dry port warehouse will be characterized by the volume of cargo exported by block trains V_{BT}. The value of $V_{ACT} > V_{BT}$, because ACT is the trunk line in the network in question, while the block trains act as feeders. Let's construct a curve of the dynamic component of the dry port container storage volume (Fig. 4).

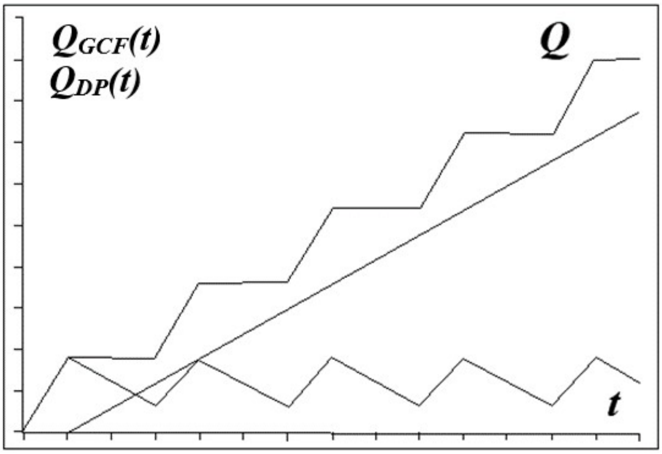

Fig.4. The dynamic component of the rear terminal warehouse volume

Having analyzed the above curve of the dynamic component of the dry port warehouse volume, we can see that in case of regular exports, the maximum values of cargo volume in the warehouse do not exceed the batch volume ACT — V_{ACT}. Consequently, the maximum capacity of the rear container terminal to handle cargo flow gives the following expression:

$$E \leq V_{ACT} + \frac{Q_{ann.} T_{keep.}}{365} = V_{ACT} + \frac{NVT_{keep.}}{NT_{ship}} = V_{ACT}\left(\frac{T_{keep.}}{T_{ship}} + 1\right) \qquad (9)$$

Full transfer of the commercial storage function to the «dry port» from the seaport, i.e. $T_{keep.} > 0$, would also require the warehouse to be able to store the ship's lot V as well. Then:

$$E \leq V_{ACT} + \frac{NV_{ACT} T_{keep.}}{NT_{ACT}} + V = V + V_{ACT}\left(\frac{T_{keep.}}{T_{ACT}} + 1\right) \qquad (10)$$

Further we propose to consider the case of simultaneous arrival of export $Q_{exp.}$ and import $Q_{imp.}$ cargo flows into the two-link system. These cargo flows can be conventionally divided into increasing cargo at warehouses (import of export cargo through Q_{CF} of dry port, import of export cargo from dry port to seaport warehouse, reception of import cargo through S_{CF} of seaport, receiving import cargo from the seaport to the dry port) and on reducing cargo at warehouses (export cargo export through the seaport S_{CF}, export cargo export from the dry port to the seaport warehouse, import cargo import from the seaport to the dry port warehouse, import cargo export through the dry port Q_{CF}).

Discussion

Similar judgments to the above allow you to analytically derive the value of the basic capacity of the warehouse for export and import directions in relation to container warehouses of sea and rear terminals:

$$E_{mar.wareh.}(t) = \int_0^t \left[q_{DP}^{exp.}(t) - q_{SCF}^{exp.}(t) + q_{SCF}^{imp.}(t) - q_{DP}^{imp.}(t)\right]dt + \frac{T_{keep.}*Q_{ann.}}{365} \quad (11)$$

$$E_{rear.wareh.}(t) = \int_0^t \left[q_{gigm}^{exp.}(t) - q_{kp}^{exp.}(t) + q_{DP}^{imp}(t) - q_{SCF}^{imp.}(t)\right]dt + \frac{T_{keep.}*Q_{ann.}}{365} \quad (12)$$

To obtain the necessary data to determine the characteristics of the warehouse of the sea terminal Emor.skl and the rear terminal Etyl.skl with simultaneous entry into a two-link system of export and import cargo flows it is proposed to use simulation modeling.

Description of the proposed model. Let there be two independent transport systems: a single-link one consisting of a seaport, and a two-link one consisting of a seaport and a dry port. Also let there be a given export cargo flow $Q_{exp.}$ and import cargo flow Q_{imp}, realized by entering the system by ships with interval T_{ship} and ACT with interval T_{ACT} ACT are characterized by cargo volume - V_{ACT}, sea ships are characterized by cargo volume V, block trains working on the line between the port and the "dry port" are characterized by cargo volume V_{BT} SCF is characterized by productivity P_{SCF}, TEU/day, while Q_{CF} is characterized by productivity P_{SCF}, ACT/day. Loading front capacity for technical cargo flow by sea and rear terminals is characterized by P_{DP} capacity, DT/day.

Formal description of the logic of the model. First, let's consider a two-link transport system consisting of a seaport and a "dry port":

Step 0. There is no cargo in the warehouses of the sea and rear container terminals. The time interval in the model is taken as 1 day.

Step 1. By rail (ACT) the export cargo arrives at the rear container terminal via a ground cargo front *(G_{CF})* and stays there for the duration of storage $T_{keer.}$

Step 2: In case of a ship's arrival scheduled for the next 10 days, the cargo is transported via a block-train system in VBT shipments to the sea term container yard, where it is unloaded if the ship is not at the berth waiting for the arrival of the ship. If a vessel is at the quay and is ready to receive the export cargo, the cargo is reloaded onto the vessel by the direct route.

Step 3: The vessel's arrival occurs in the Tshirin interval. After the vessel arrives, the import cargo is completely unloaded from its board via S_{CF} and placed in the container yard of the marine terminal.

Step 4. After unloading of import cargo in volume V at S_{CF} is completed, the export cargo is loaded onto the ship (and the size of the export cargo batch can be either smaller or larger than the import cargo, but no larger than the maximum vessel capacity) for shipment to consignees by sea.

Step 5. After completion of unloading of the first batch of import cargo greater than or equal to VBT, this batch is loaded into block trains and shipped to the "dry port" warehouse on the same day.

Step 6. The import cargo is transported by rail to the container warehouse of the rear terminal through and stays there for a certain period of time T.

Step 7. Once the volume of cargo in the dry port warehouse is greater than or equal to V_{ACT}, the batch of imported cargo V_{ACT} is loaded into ACT and shipped to the consignees.

Step 8. The model consists of a series of 365 intervals, each equal to one day. Next, consider a single-link transportation system:

Step 4. When the import cargo in volume V is finished unloading at the S_{CF}, the export cargo begins to be loaded onto the ship (and the size of the export cargo batch can be either smaller or larger than the import cargo, but no larger than the maximum capacity of the ship) for shipment to the consignees by sea.

Step 0. There is no cargo in the warehouse of the seaport. Time interval in the model is also taken as 1 day.

Step 1. The export cargo arrives by rail (ACT) to the container warehouse of the seaport through Q_{CF} and stays there for some period of storage T keep.

Step 2: The arrival of the ship occurs in the interval Tshir. After the arrival of the ship from his board through

SCF fully unload the imported cargo, which is placed in the container warehouse of the sea terminal.

Step 4. After unloading of import cargo in volume V on SCF is finished the loading of export cargo on the vessel (and the size of export cargo may be either less or more than import cargo, but not more than maximum tonnage of the vessel) for the delivery to consignees by sea.

Step 5. When the first batch of import cargo greater than or equal to the V_{CT} is unloaded, the V_{ACT} import cargo batch is loaded into the ACT and shipped to the consignees. Step 8. The model consists of a series of 365 intervals, each equal to 1 day.

The resulting model allows the study of the main parameters of technological interaction between sea and rear container terminals in one- and two-link systems. The model can be used to obtain data on the dynamics of import and export cargo import/export to warehouses, maximum and minimum cargo volume in warehouses at each moment of time.

Next, an experiment with the model is conducted. Let export cargo flow be Q_{exp} 30000 TEU/year, import cargo flow be Q_{imp} 45000 TEU/year. Flows are realized by uniform arrival of ships to the system with 10 day interval and VPC with 3 day interval. Cargo storage period will be 7 days. Obtained simulation results are shown in Fig. 5 - 7.

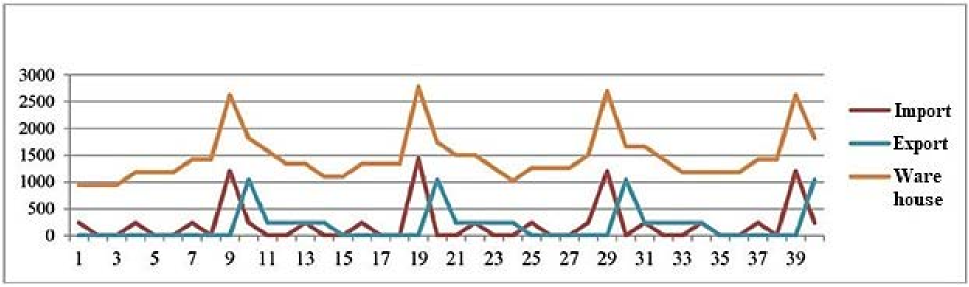

Fig. 5. Dynamics of cargo volume change at the seaport warehouse in the single-link system

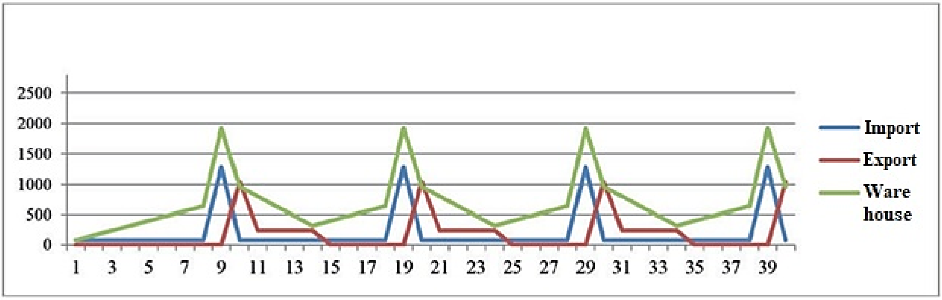

Fig. 6. Dynamics of cargo volume change at the seaport warehouse in the two-link system

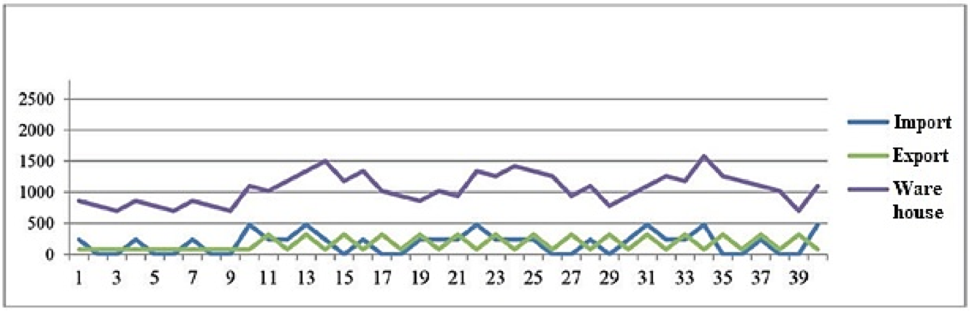

Fig. 7. Dynamics of cargo volume change at the «dry port» warehouse in the two-link system

Analysis of the results of the experiment allows us to draw the following conclusions:

1. The systems successfully handle the arrival of export and import cargo. At the same time, the systems serve 38 ship calls and 122 arrivals of CCS. Work in the two-link system is carried out through the daily operation of one to three block trains.

2. In the single-link system with given input data the average number of containers in the warehouse of the marine terminal is 1489 TEU, while in the two-link system - 710 TEU (while the average number of containers in the warehouse of the rear terminal is 1129 TEU).

3. In a single-link system with given input data, the maximum number of

containers in the warehouse of the marine terminal is 2700 TEU (> 2V), whereas in a two-link system it is 1920 TEU (< 2V), which is 28 % less.

The conducted experiment and simulation modeling allow us to estimate the required maximum capacity of sea and rear container terminals when processing export and import container flows. If the commercial storage function is fully transferred to the rear terminal (i.e. for the sea warehouse $T_{keep} = 0$), the maximum required capacity of the sea container terminal and will give the following expression:

$$E \leq 2\left(V + \frac{Q_{ann.} T_{keep.}}{365}\right) = 2V \quad (13)$$

Full transfer of the commercial storage function to the «dry port» from the seaport (i.e. for the rear terminal $T_{xp} > 0$) will require the warehouse to be able to store both the shipload V and to smooth out fluctuations arising from the unequal approach of sea ships ΔT_{sud}. Thus, the maximum storage capacity of a rear container terminal will be expressed as:

$$E \leq 2(V_{ACT} + \frac{NV_{ACT} T_{keep.}}{NT_{ACT}} + V + V_{BT} \Delta T_{ship} = 2(V + V_{ACT}\left(\frac{T_{keep.}}{T_{ACT}} + 1\right) + V_{BT} \Delta T_{ship} \quad (14)$$

The introduction of an additional link into the transportation chain - a rear container terminal - leads to an increase in the total size of warehouses - Emar. wareh.+ Erear.warex. compared to the warehouse of the single-link Ewareh system, i.e. Emar.wareh.+ Erear warex. > Ewareh. The main reason is the need to compensate for two pairs of non-uniform batch sizes and vehicle arrivals.

Conclusions

1. The functioning of the logistics element - the sea container terminal - in the single-link system leads to the emergence of excess or deficit of cargo in storage. In this regard, the port should be able to store surplus stock, arising from delays in export due to the non-arrival of a vehicle (vessel), as well as the accumulation of "safety" stock, designed to load the vessel, which arrived earlier.

2. In case of organization of functioning of a two-link transport chain sea terminal - rear terminal, the operator of sea terminal gets an opportunity to reduce the area for storage on the expensive port territory, to reduce the fleet and to evenly distribute the work of transshipment equipment at the terminal, and also gets an opportunity to react adequately to changes in the size and frequency of supply of required lots.

3. In case of management of technological interaction channels an operator of a sea terminal gets an opportunity to solve any task, up to complete elimination of storage at a sea terminal.

4. the use of analytical methods makes it possible to derive the values of the base capacity of warehouses of the sea and rear terminals for export and import directions.

5. Simulation modeling makes it possible to assess the impact of the unevenness of the arrival of vehicles on the value of the required storage capacity of sea and rear terminals, as well as to obtain data on the required level of technological interaction between terminals, which can ultimately be used to plan the work of transport and infrastructure facilities.

6. In the case when the specific cost of storage at the sea warehouse is much higher than that at the rear warehouse, the option of using a two-link system in the transport chain: sea and rear container terminal, is more preferable.

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CONTENT

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