Ошибки возникают в случае активизации более двух путей или превышения скоростью ветра и температурой контрольных значений (20 м/с и –30 С). А также при одновременном превышении этих предельных значений, что показано в качестве примера на рис. 7. В таблице 3 приведена зависимость кодов ошибки от фактора, вызвавшего её.

С целью проверки возможностей решения широкого круга задач с использованием разработанной модели (таблица 1) рассмотрим вариант ситуационного моделирования процесса перегрузки минеральных удобрений.

Возьмем работу программы при моделировании перегрузки для двух путей. Предположим, что необходимо перегрузить 25000 т груза с первого и второго складов. Результаты моделирования показали, что для перегрузки надо затратить 15 часов (рис. 8). Функция путей в этом случае имеет вид:

W= [0 1 1 0 0 0 0 0].

ЗАКЛЮЧЕНИЕ

Представленные в статье подходы к решению задач ситуационного управления с использованием методов виртуальных технологий позволили разработать структуру виртуального предприятия и показать её реализацию в виде интернет-сайта. Электронный обмен данными с ОАО «РЖД», клиентами Мурманского морского порта и их автоматическая интеграция в систему виртуального предприятия помогают осуществлять более четкое планирование работ, равномерное пополнение складов, обеспечивают своевременность поставки грузов, уменьшают риск затора вагонов и улучшают взаимоотношения с клиентами.

Разработка математической модели управления процессами перемещения грузопотока минеральных удобрений в виде граф-модели и её аналога – матричной модели дает возможность решать задачу оптимизации различных по содержанию вариантов перемещения сыпучих грузов в пределах перегрузочного комплекса с учетом заданной интенсивности погрузки судна, а также внешних факторов, в том числе и погодных.

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BULK FREIGHT AT THE PORT: SITUATIONAL HANDLING

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ABSTRACT

The article describes study on approaches towards solution of a problem of situational control of transshipment of goods at the sea port on the basis of virtual technology and mathematical simulation. The results of the study are demonstrated with the help of examples of Murmansk sea port and Internet-site, which serves to prove the efficiency of electronic data exchange.

ENGLISH SUMMARY

Background. *Development of Murmansk transport nodal center (MTU) is considered actually as a complex task of strategic importance and its implementation includes modernization and development of main transportation modes (road, rail, sea, air) and of logistics and warehouse structures. Development of MTU can have an outlook on its transformation* *into one of the world's largest sea hubs. The studies held previously have shown that freight turnover will be doubled and under favorable conditions can be increased by five times. Main goods handled at the port are coal, apatite concentrate, metals. The exported goods represent 93,4% of total freight turnover, while bulk goods represent about 87%.*

But the forecasted development of MTU is only possible if there are consolidated data on movement and handling of goods flows, effective logistics system, good operational management at all stages of goods transportation.

Absence of integrated intelligence control systems, of regional and port logistics centers is now a problem, the solution of which is the only way to provide freight turnover growth, commercial speed and reliability of transportation services.

Important changes in organization of delivery of external industrial goods happened during last years. It is first of all explained by the transition to the market of individually shaped services, by wide use of multimode transport, introduction of new information technology. It was a reason of enhancing of forms of services offered to forwarders of goods, transforming the relations between customer and transport organization to situation choice from a variety of possible variants.

So the freight flows require constant decision of single situational transportation problems, including operational planning, and fulfilment of assignments submitted to individual objectives.

The laying out of expensive logistics for such problems is often economically inefficient. So the foundations for solution of those problems should include optimal resource consumption, painless liquidation of consequences of a command fulfillment, low costs of generating and operation of logistics services, possibility of scaling, flexibility. Development of informatics also influences logistics, growth of customer demand, and possibilities to enhance efficiency of transport systems.

Informatics progress is characterized by three components: 1) database development; 2) enhancement of network technology (FireWire (iLink), Modem, LAN – Gigabit Ethernet), including wireless networks (GSM, GPRS, EDGE, CDMA) and consequently 3) Internet- technology (WAP, MMS, WEB).

The most important resource, capable of imposing deep impact on competitiveness and investment image of business entities, is corporate knowledge. And intelligence control systems with specialized software, new methods of organization of network capacity are within the guidelines of database development.

There are two trends of developing logistics in information environment: information trend, that monitor information flows, and virtual, that is focused on logistics operations of enterprises using virtual resources.

Objectives. *The article is intended to show the ways to create the system of situational management and control of goods' transshipment in the sea port.*

Analysis of practices of control of technical systems leads to necessity to create tools of automation that permit a real time optimal regulation and functioning control of multicriterion and random processes. Implementation of such approach supposes operational assessment of a situation and forecasting of its further development [1]. Implementation of situational process control in transport systems permits making relevant decisions in indeterminacy and uncertainty conditions following the principle «situation – strategy – action» [2].

Methods. *The authors have used complex methods of virtual technology to conduct their study.*

There are studies which are known as been intended to solve situation problems with the help of virtual methods of organization and control [5,6]. The authors underline those of them that contributed to implementation of industrial systems and methods of virtual enterprise into technological process. Main technologies aimed at management, planning and designing are CAE, CAD, CAM, SCM, ERP, MPR-2, SCADA, CNC, CRM, S&SM and similar, that make part of systems of data control CPC or PLM. Most popular systems used in business projects are ERP, CRM, SCADA, most popular technologies are Workflow, CASE, CALS, intended to implement methods of virtual enterprise (VE) [3].

Application of VE methods supposes searching for technology of irregular industrial freight flows and laying out of logistics system of freight delivery from an enterprise (forwarder) to customer with reducing labor intensity of technological decision making [4].

While using intelligence systems (IS) it is possible to store data on realization of complex interaction of underformalized systems with external environment, including cases of nonstandard and emergency situations. Development of adaptive models of formalization of knowledge in a certain field on the basis of such data permits to modernize algorithms of computing system capacity and models of behavior of decision making person [5, 6]. Functional capacity and interface of VE considerably depend on possibility to formalize description of reality and on fullness of application of all the diversity of mathematical methods of data processing (continuous, fractal, interval, fuzzy, multi agent, neural network, linguistics methods etc.) So the authors underline the virtual necessity to create special formal apparatus of uniform presentation of the models, synthesized by different methods and tools in computing environment [6, 7].

In order to build poly-model complexes usually two basic principles are used: of limit synthesis and of poly-model competitiveness and complementarity. Regardless of importance of each principle taken separately, the main sense of proposed approach is focused on their deep interrelation allowing to create self-organizing IS, capable of storing and enhancing their parameters via self-learning and self-organization on the basis of internal active status of the system [5].

Results. *In a proposed solution all the parameters and variables of models will be called tests. Let $\{\tau\}$ be a multitude of elementary tests with the help of which all the factors, circumstances and phenomena relevant for development of VE are described. Elementary character of a test means that its result will be expressed as «test = value». The immediate result will be expressed through $\underline{\tau}$.*

The results of the tests could be selected from within different domains of databases. In order to fix that domain T was taken as a multitude of results of test τ, the authors use notation τ/T. By taking different domains it is possible to manage generality of results of the same test [5, 7]. To realize one of the variants of descending determination, and element of discrete domain can be supplied with one or several functions of attribution, namely: T = {a {μ_a}; b {μ_b}; c {μ_c};...}, where μ – functions of attribution (influencing descending determination only). In general case descending determination of a multitude of tests is described by mutually concerted processes, which are ready to realize creation of a structure of VE.

For instance the article studies stages of development of VE for Agrosphera corp., connected with handling of loose freight (mineral fertilizers) in Murmansk sea port. VE needs several databases (DB). The DB were developed under Microsoft Access. The management of DB is realized by specialized DBMS within Microsoft SQL Server. The first DB will show quantity of freight which an organization possesses. In reality the freight is allocated at the warehouses of manufacturing enterprise. Knowing quantity of the freight it is possible to accept or to reject the applications of clients.

The article describes the fields that should be filled-in («kind of freight», «goods forwarder», «quantity of those goods with a client», «total quantity of the goods of the same kind with all the manufacturers»). The second DB should contain information on the process of fulfilment of application and the article describes the fields to be filled-in (date of application, kind of goods, client, date of arrival at transshipment point, lay-days – time of loading days concerning a vessel, date of shipment by sea transport, date of arrival of goods to customer).

Realization of transport VE. Realization of a structure of VE permits to solve problems of irregular industrial freight flows and laying out of logistics system of freight delivery from an enterprise (forwarder) to customer with reducing labor intensity of technological decision making. The obtained technological, centrally managed chain is a virtual transport enterprise (pic.1). The system management is implemented with the help of virtual center as a reaction to feedback from the elements of technological chain and from the points of generating (S_1) and terminating (S_5) of freight traffic flow and logistics resources.

In order to realize virtual enterprise a special Internet-site was developed. Its main page is shown in pic. 2. One can go to main chapters of the site by using inlays «to order freight», «for freight forwarders», «to track the freight».

Using the section «to order freight» a client can select for a kind of freight that he needs (now different types of mineral fertilizers and coal could be selected).

The section «for freight forwarders» is intended for placement of information at the warehouses.

The section «to track the freight» is intended for freight customer. The tracking is supposed to be made with GLONASS system. GPS-trackers will be put on the rail cars and other transport vehicles.

The information on planned and respected schedule reduces time necessary to prepare the reports and consequently reduces time for analysis of planned handling operations at the port and permits correction of shift and daily operational plan.

Analysis of information reduces risks of «lost» rail cars, loading of tracks and rail car leasing costs, time of decision making. Electronic exchange of data with JSC Russian Railways, port clients, and data automatic integration in the VE system permit to achieve more regular planning, balanced warehouses loading, enhance port-client relations.

Features of transshipment of mineral fertilizers. The Russian capacity to produce mineral fertilizers is sufficient to fully cover national demand and to export yearly about 35 mln t.

Agrosphera corp., is a stevedore company, transshipping mineral fertilizers at Murmansk sea port. Corporate terminal is intended to load fertilizers with special conveyer equipment from rail car to a ship, from warehouse to a ship, and in a c mode that combine the first two modes. The delivery to the port is executed by rail in hopper cars. The process of transshipment is described in the article and is shown in pic.3.

Situational simulation of fertilizers' terminal. A general model of terminal's operation can be expressed as a cortege, regulated set of elements called cortege components:

DTMU = <OP, RP, Z, MF, PK >,

where: OP – multitude of operations; RP – multitude of proper resources; Z – multitude of applications (commands) for handling; MF – multitude of meteorological factors; PK – multitude of quality indices of logistics services.

In order to study features of any system by mathematical tools it is necessary to proceed with formalization, to build mathematical model. Optimization of variants of transshipment in order to provide necessary intensity [9] could be achieved by presenting model of transshipment complex as a graph, and by presenting its analog as a matrix model.

In order to build graph-model the authors present subsystem of loading and unloading as the peaks of a graph: K = {K1, K2,., KN} (N = 1...13).

Multitude of arcs $E = \{E_{12}, E_{23}, ..., E_{12,13}\}$ (direction of goods traffic) are elements of graph-model V (K, E) of transshipment processes.

Graph V is a oriented one as all the arcs are oriented. It is possible so to present it as a displacement matrix: $M=||m_{ij}||$, where i – lines, presenting peaks of the graph, and j are columns (one for each arc) [9]. Elements of matrix m_{ij} are determined as follows:

$$m_{ij} = \begin{cases} 1, & \text{если дуга выходит из i-й вершины в j-ю;} \\ -1, & \text{если дуга выходит из j-вершины;} \\ 0, & \text{если дуга не входит и не выходит из вершины.} \end{cases}$$

where 1 – if arc goes from i-peak to j-peak
–1 – if arc goes from j-peak
0 – if arc doesn't goes out neither comes to any peak

Displacement matrix is illustrated by table 1. The lines of matrix show directions of goods displacement within transshipment process. E multitude are variants of transshipment processes of which definite and finite allocation of goods is characteristic. For each moment t probability of any state of the system in future depends only on its present state. System states are interconnected (by transition from i-state to j-state). So state of the management system is an allocation of freight traffic flow in one of graph's peaks. Dislocation of the traffic from one peak to another represents change in system state. Graph shows it as dislocation of goods from K_i to K_j.

Solution of minimization problem supposes exclusion of a case when any part of goods will pass by conveyer which is already loaded. The minimized graph is presented in pic.4.

The junctions between objects in the graph are characterized by functions of the tracks – W1..W7. Each function is interpreted by transporters of a contour of traffic of fertilizers.

The obtained functions of tracks don't contain repeating of conveyers:

W1: transporter lines 1002 и 1003;

W2: transporter line 1004;

W3: transporter lines 1004, 1005;

W4: transporter lines 1004, 1005, 1006;

W5: transporter lines 1010, 1011, 1017, 1019 (ПМ);

W6: transporter line 1007;

W7: transporter line 1008;

W8: transporter line 1009.

Matrix of function of the tracks is expressed as:

W= [W8 W7 W6 W5 W4 W3 W2 W1].

So information on a route of goods shall be processed as a model input data, matrix of tracks (which determine by which transporter line the signal passes) shall be processed as output. A model realized under Simulink and a Stateflow chart are presented respectively in pic. 5 and 6.

Realization of an algorithm of dislocation matrix (table 1) is realized by sending «0» or «1» to the relevant input of the block. Inputs Rt_1, Rt_2, Rt_3, Rt_4 are intended for routing of mineral fertilizers (table 2).

Block Weight receives information on freight quantity in tons (intended for transshipment to the vessel). Blocks Store 1, Store 2, Store 3 show freight quantity in tons at warehouses 1, 2, 3.

The program is actuated after inputting of necessary data and selection of routing. Block Time shows time in hours necessary to accomplish this handling operation. Blocks Store 1 after, Store 2 after, Store 3 after show freight quantity which is still in stock at respective warehouses. Block Error is intended to inform about errors. Errors occur when two or more tracks are actuated or if wind speed and temperature rates exceed control values (simultaneous exceeding of those two parameters is shown in pic.7; table 3 illustrates error codes caused by different factors).

In order to verify possibility to solve wide spectrum of problems using developed model (table 1) the authors studied a variant of situational simulation of transshipment of mineral fertilizers for two tracks. If it is necessary to handle 25000 tones from warehouses 1 and 2 then according to the simulation it will take 15 hours (pic. 8). Function of tracks is in that case expressed as follows: W= [0 1 1 0 0 0 0 0].

Conclusions. *The approaches of solution of problems of situational management with the help of virtual technology permitted to develop the structure of virtual enterprise and to present its realization via Internet-site. Eletronic data exchange with JSC Russian Railways and with clients of Murmansk sea port and its automatic integration into VE system allow regular planning of operations, balanced warehouses loading and in-time delivery, enhance relations with the clients.*

Development of mathematical model of management of processes of dislocation of freight traffic of mineral fertilizers under the form of a graph-model and its analog matrix model allows solving of the problem of optimization of different variants of dislocation of loose goods within transshipment complex, taking into account the assigned intensity of the process of ship loading and external factors including weather conditions.

Key words: sea port, multimode traffic, bulk freight, situational management, mathematical model, Internet-site, electronic data exchange.

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