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INCREASE OF EFFICIENCY OF INTERACTION OF PRODUCTION AND TRANSPORT IN THE LOGISTIC CHAINS OF MATERIAL TRAFFIC OF ENTERPRISES

Summary. The problems of interaction of production and transport in micro logistic flows of enterprises are considered. On the basis of identification of the characteristics of processes the substantive provisions of methodology of forming of material traffic chains in transport-freight complexes are developed, a model and algorithm of optimization of material traffic chains on a logistic criterion is offered

ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ ВЗАИМОДЕЙСТВИЯ ПРОИЗВОДСТВА И ТРАНСПОРТА В ЛОГИСТИЧЕСКИХ ЦЕПЯХ МАТЕРИАЛОДВИЖЕНИЯ ПРЕДПРИЯТИЙ

Summary. Рассмотрены вопросы взаимодействия производства и транспорта в микрологистических потоках предприятий. На основе идентификации процессных характеристик разработаны основные положения методики формирования цепей материалодвижения в транспортно-грузовых комплексах, предложены модель и алгоритм оптимизации цепей материалодвижения по логистическому критерию

1. UP-TO-DATE STATE OF QUESTION. STATEMENT OF A TASK

Processes of material traffic at metallurgical enterprises, which include providing by raw material, preparation and production of products, marketing and sale of the finished products to the consumer, represent in the aggregate the intra-production logistic and fall into category of micro flowing processes. On the separate links of this chain (at the reception of raw material, to the transmission of intermediate products on a technological chain between the main production redistributions, shipping of the finished products) railway transport becomes an important component of material traffic process.

The external and internal (technological) transportations of enterprise, realized by a railway transport, are considerable in volume (in 10 – 12 times exceeding the volume of shipment of the finished products) and characterized by sufficient stability.

Transition on the market mechanisms of management complicated considerably the operating conditions of railway transport and was especially negatively reflected on external transportations. Above all things, it is related to the substantial change of principles of interrelations of enterprises mainly with railway transport, as the pay for time of the use by carriages of external park (EP) is entered instead of car detention rates. In addition the operative supplies were reduced to the minimum values on enterprises, the irregularity of deliveries and supply of raw material increased. A nomenclature was broadened, the quality requirements and observance of delivery dates of the finished products were raised. The number of operators-carriers increased, an amount of technically defective carriages of EP had grown.

Big metallurgical plants receive every day to 700 – 800 carriages with iron containing materials, fluxes and other kinds of raw material. After their unloading about 40 % carriages is used on the doubled operations, - shipping of the finished products to the users. The middle detention of a car of the external park, going under the second operation (loading), makes 40 – 50 hours. However, an actual duration of staying of the EP carriages on enterprises achieves 75 – 80 hours and more. The given situation results in considerable extra transport costs and production losses [1].

The process of car flow advancement at the doubled operations is the consistently executable groups of technological operations which are regulated at times, sufficiently near to the optimum time values. Deceleration of car flow advancement and additional inter operational detentions arise up in joint points, in transition from one group of technological operations to other (fig. 1).

The sections of interaction of transport and production shops or transport-freight complexes (TFC) of unloading of raw material and loading of the finished products are characterized by the most inter operational detentions. Such detentions make up to 70 % of duration of the doubled operations. Such situation is conditioned to that production and transport work in a different rhythm, and the level of the informative providing on the elements of this interaction does not allow to react on nascent problems in the proper time.

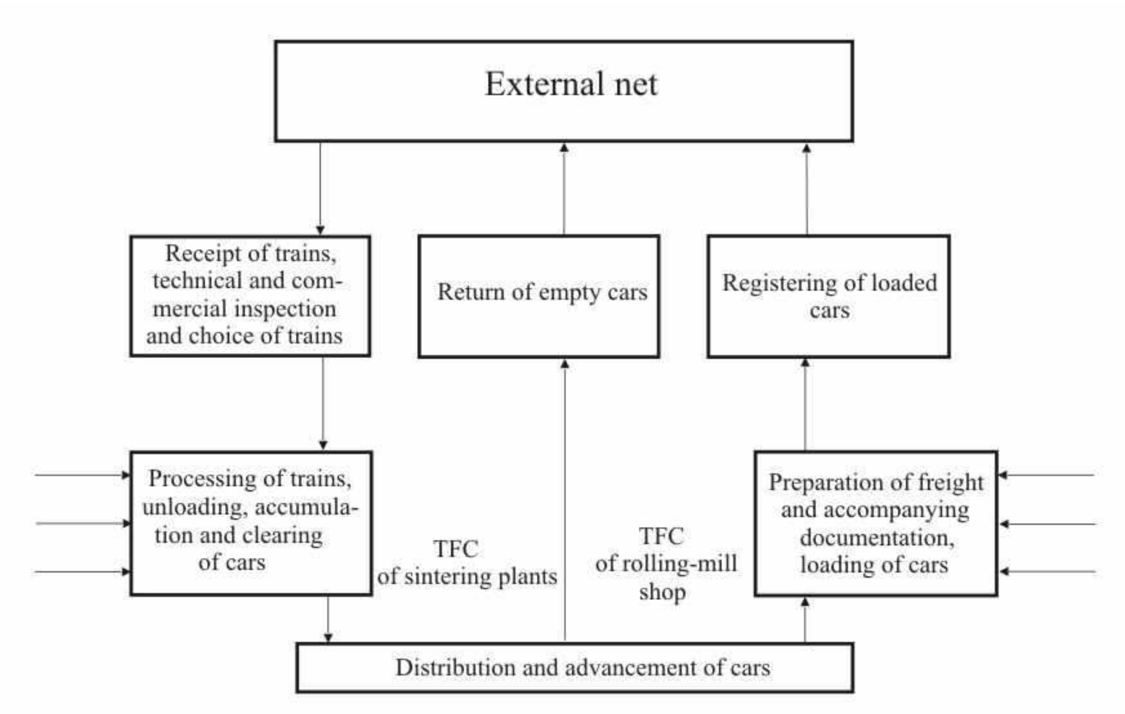

Fig.1. Chart of car flow advancement at the doubled operations
Рис. 1. Схема продвижения вагонопотоков при сдвоенных операциях

The conducted analysis shows that the problem of radical increase of efficiency of control by processing of car- flow becomes very actual and important on the given stage. It is created on a new technological and informative base and oriented to continuity of the transport providing of production process of enterprise.

Conception of a new approach consists in transition on principles of logistic management by interaction of production and railway transport on the base of the analysis and detection of disproportions and losses which result in growth of costs of transportation at maintenance of basic production [2].

Logistic approach is based on community of production interests of participants of process that is on technological, organizational, informative and financial unity. It allows from new positions to perfect technological charts and organization of pass and processing of car-flows for providing of timely delivery of loads to the production workshops and delivery of the finished products to the consumers with minimum costs of transportation.

The purpose of logistic management is taken as a matter of fact to organization in TFC (as the system) necessary communications of its modules (as subsystems) for giving to the complex of properties of integrity, as an effect of optimization of all system does not mean that all constituents of the subsystem will work in the optimum mode.

The given pre-condition of creation of mechanism of logistic interaction in TFC is based on the following principles of theory of optimization:

- the optimum state of every subsystem in the system is less effective, than the optimum state of the system,
- optimization of the state of the system results in the suboptimum states of subsystems constituting the system.

A principal conclusion from these principles is that the mutual co-ordination of subsystems in organization and management by the logistic system is very important for achievement of effective final result.

Increasing significance of problem of increase of efficiency of management by railway transportations requires acceleration of transition of production and transport on logistic principles of interaction. However, neither production nor transport is not methodically prepared for it. The conducted analysis of theoretical and scientific-practical publications for the last years has shown that the complex of questions of logistic control by micro-flowing processes is lighted up and studied insufficiently [3].

The purpose of the given work is identification of process of material traffic in TFC of enterprises and development of method and model of forming and optimization of logistic chains.

2. SUBSTANTIVE PROVISIONS OF METHOD OF FORMING OF CHAIN OF MATERIAL TRAFFIC IN TFC

The conducted analysis allows to consider that the process of material traffic in TFC represents micro-system (subsystem) of the big production-transport system of enterprise and executes the function of joining up of links incoming in it in single transport-freight technology. In this connection a primary concern is identification of the micro-flowing process of TFC as base for transition on logistic principles of control by interaction of production and transport. Decomposition of process of processing of load in TFC, as the system, allowed to identify the parameters of process and to develop the following substantive provisions of method of forming of chains of material traffic [3, 4].

1) The process of material traffic in TFC executes the integrating function, uniting its elements in the integral continuously functioning system. The feature of the last is multiphase of servicing that is transformation of material flow under action of some phases of service, each of which realizes an independent function.

The principal flow charts of material traffic process in TFC are presented on the fig. 2

At receiving of raw materials the phase transformation consists in consecutive transition of the freight from the phase of «train flow » (technical and commercial reception of carriages), into the phases of «car flow» (disbandment of routes), «freight traffic» (unloading of carriages) and then into «raw material flow» (feed on storages of sintering plant).

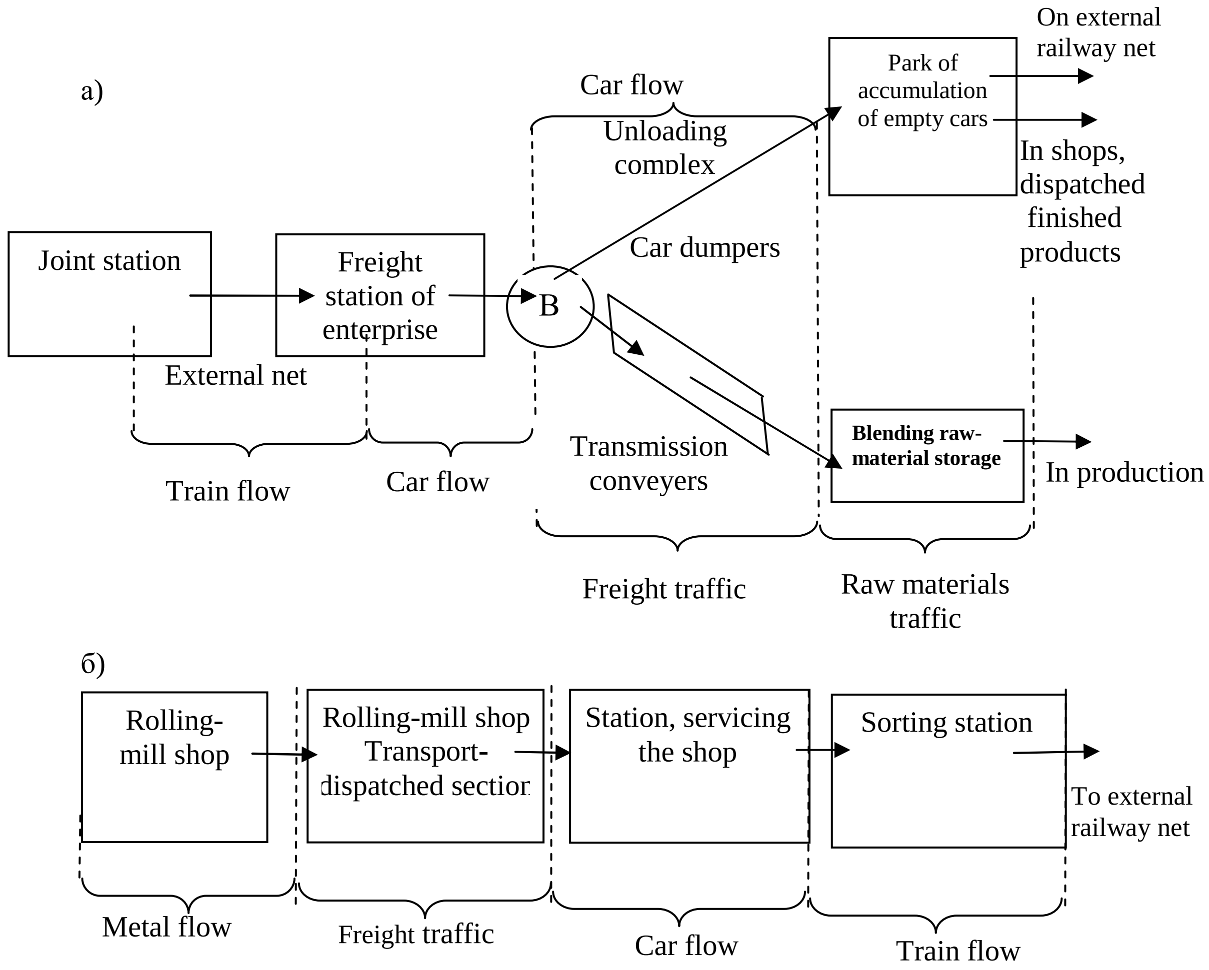

Fig. 2.Principal flow charts of micro-flowing processes of transport-freight complexes of sinter plant (a) and rolling-mill shop (b)
Рис. 2. Принципиальные схемы микропотоковых процессов транспортно-грузовых комплексов аглофабрики (а) и прокатного цеха (б)

At shipping of the finished products the freight in consecutive order passes from the phase of «metal flow» (preparation of metal and its quality control) into phases of «freight traffic» (transport-expeditionary operations and loading of metal in carriages), phase of «car flow» (forming of groups of carriages) and, finally, into the phase of «train flow» (handing over of carriages with a metal on an external network).

Consequently, in the process of the TFC functioning every phase of material traffic will realize a certain function, and their integration must provide the complete cycle of service in accordance with a rate which sets a production object.

2) The functions realized within the framework of every phase determine the method of maintenance of material flow, representing the finished cycle of technological operations, which are functionally and structurally amalgamated in the independent module. For implementation of complex of the operations plugged in the module, various technical devices (points of inspection of carriages, reception-and-dispatching and loading tracks, sorting devices), specialized equipment (locomotives, car dumpers, hoisting-and-conveying machinery) are used, the prepared operating personnel is attracted.

The process of material traffic requires documentary (informative) accompaniment, as well as adequate managing actions.

Consequently, in every module the freight is identified by a set of indexes including: rate of material traffic, parameter characteristics of the freight (gravimetric, volumetric, overall, physical – and-mechanical and others), used container and terms of transportation. The change of these indexes takes place in the process of realization of function of servicing in every module and the freight from the transport state is transformed into raw material prepared for the use in production (feed of raw material), and metal products – in a freight responding to the conditions of transportation to the consumer (shipping of products).

3) Any transport-freight process includes leading (limiting) link (module), operating ability of which is determined from the condition of providing of the rate of material traffic, set by a production process. In the process of material traffic in the TFC the functioning of production and transport in a single rhythm is provided by the leading module, and redemption of possible rejections and synchronization of quantitative parameters is achieved on the basis of application of logistic principles.

Researches ground to consider that in the micro-flowing processes of interaction of production and transport the role of leading link belongs to the phase of freight traffic. The technological operations on unloading or loading of the freight determining the conditions of freight traffic are carried out in this module in the rate set by production, and parameter characteristics of the freight are taken to the level responding to requests of production technology of transportation. That is, here is actually the transfer of the freight from main to the intra-production transport (reception of raw material), and vice versa – from intra-production transport to the main transport (shipping of products).

For the micro-flowing process of TFC at servicing of the sintering plant the leading links are car dumpers (CD) with transmission conveyers, for TFC, providing loading of products in the rolling-mill shop, - transport-expeditionary section (TES). Thus the stable functioning of transport-freight complexes is based on the effective organized interaction of the leading modules with a production object and railway transport (fig. 3).

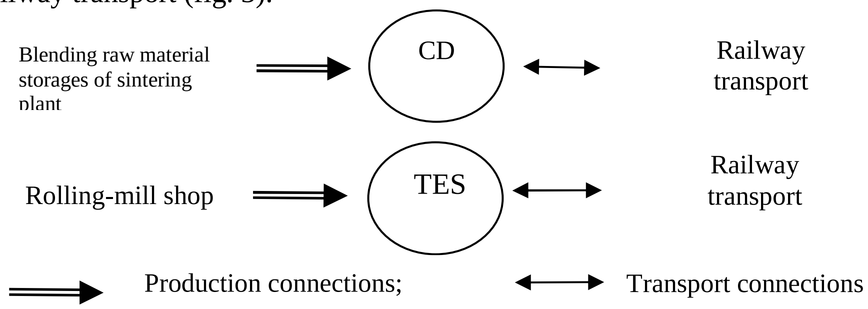

Fig.3. Chart of organizational interaction of the leading modules of TFC
Рис. 3. Схема организационного взаимодействия ведущих модулей ТГК

4) For up-to-date conditions an error of rhythm of work of production and transport of integrated iron-and-steel works is characteristic. Therefore perfection of production management becomes a determinative factor in the decision of problem of increase of efficiency of interaction of transport and production.

The flowing processes are characterized by three types of management: by train flows, car-flows and freight traffics. The first two are enough for providing only actually of transportations of enterprise. In market conditions, at the decision of question of increase of efficiency of interaction of production and transport, the management by freight traffics comes out first. Deep analysis shows that the management by freight traffics can create a new positive effect as allows to redistribute part of functions of the leading module to the contiguous phases of flow process, transforming or substituting for dynamic backlogs - static ones and, vice versa, using additionally organizational or technical reserves.

The specific feature of micro-flowing processes is also their multi-layer structure, as in the single process of management of material traffic the modules, forming the system, are intercommunicated by flows of documents and information also concomitant to it. Presently they are divided in space and in time and their synchronization is an important problem.

5) A different rhythm of work of production and transport stipulates idle times and outages on a joint between them. Their production causes are not readiness of production to the reception of raw material, absence of the finished products of the required amount and quality, not readiness of commercial documentation. In its turn transport factors cause delay in the feed of empty or dispatching of the loaded carriages, ill-timed receipt and transfer of information.

The lack of coordination of rhythm of work is focused in the leading module (on the phase of freight traffic) of material traffic. Therefore for the criterion of management by micro-flowing processes in TFC it is necessary to take the duration of technological operations of processing of material flow in the leading module, determined as a logistic norm.

The offered method allows to form the logistic chain of material traffic for various TFC.

3. MODEL AND ALGORITHM OF OPTIMIZATION OF PARAMETERS OF CHAIN OF MATERIAL TRAFFIC INTFC

Duration of technological operations of processing of material flow in the leading module must take into account multi-layer structure of material traffic, interconnections with previous and following modules on a horizontal line and vertical line and be determined on the basis of modeling of process of material traffic [3, 5].

In the process of material traffic in the TFC three types of sequences of operations it is possible to present as vector-scalar component, which form the examined logistic chain:

$$\left.\begin{aligned} a_1 \to a_2 \to \ldots \to a_n \\ u_1 \to u_2 \to \ldots \to u_k \\ g_1 \to g_2 \to \ldots \to g_e \end{aligned}\right\} \qquad (1)$$

where «$a_1 \to$ » - element of chain of material flow in a unit (a_1 – magnitude of flow; «→ » - the vector of moving of flow, compared in course of time and distance of moving; i – 1,…, n); «$u_1 \to$ » - element of chain of information about material flow (u_1 – volume of information; «→ » - addressee of information transfer; i= 1,…,k); «$g_1 \to$ » - element of chain on drafting and transmission of documents about material flow and its moving (g_1 – number or volume of document; «→ » - addressee of transmission of document; i = 1,..., e);

The expression (1) determines a functional-logistic structure of chain of material traffic and specifies on horizontal communications on moving of material flow and proper communications on flow of information and documentary flow. Thus with the change of index of magnitude a there is the change of place of material flow and temporal co-ordinate, and the magnitude of flow (scalar measurement) does not change. The same on the index of quantities of u and g there is the change of place of origin, processing, transfer and reception of information or documents, accordingly $\{a_i\}$, $\{u_i\}$, $\{g_i\}$ are some well-organized sets.

Between the examined processes there is functional intercommunication and interdependence, which is reflected by vertical communications. Taking them into account the expression (1) assumes such form:

$$\left.\begin{array}{l} a_1 \to a_2 \to \ldots \to a_n \\ \updownarrow \quad\ \updownarrow \qquad\quad \updownarrow \\ u_1 \to u_2 \to \ldots \to u_k \\ \updownarrow \quad\ \updownarrow \qquad\quad \updownarrow \\ g_1 \to g_2 \to \ldots \to g_e \end{array}\right\} \qquad (2)$$

where ↕| - direct and reverse communications between technological processes with material, informative and documentary flows.

Thus the examined logistic chain of material traffic is composition or aggregate of logistic flows, each of which is subject to corresponding algorithmic presentation with taking into account of vertical and horizontal communications.

Expressions of elements of chain will look as follows:

on material flow –

$$A(t) = a_1 \xrightarrow{t_1} a_2 \xrightarrow{t_2} \ldots \xrightarrow{t_n} a_n; \qquad (3)$$

on information about material flow –

$$U(t) = u_1 \xrightarrow{t_1} u_2 \xrightarrow{t_2} \ldots \xrightarrow{t_n} u_k; \qquad (4)$$

on documents about material flow –

$$G(t) = g_1 \xrightarrow{t_1} g_2 \xrightarrow{t_2} \ldots \xrightarrow{t_n} g_e. \qquad (5)$$

Transition from one element of chain to other in time and in linear space is shown by the sign of «→». As the quantities of flows are satisfied to principle of additivity, the expressions (3, 4, 5) can be written down in a form

$$\left.\begin{array}{l} A(t) = \sum a_i(t_i) \\ U(t) = \sum u_i(t_i) \\ G(t) = \sum g_i(t_i) \end{array}\right\} \qquad (6)$$

At passing of freights through the TFC modules technological operations are conducted with them. Time on implementation of such operations (T_{tech}) is rationed, and also there is expectation of implementation of subsequent technological operations, time of which (T_{exp}) carries a probabilistic character. These two constituents form time

$$t = \sum t_{tech} + \sum t_{exp} \qquad (7)$$

The expenses of time, determined on a formula (7), are set on material flow without taking into account time, caused by the mutual influencing on informative and documentary flows.

Examined three types of logistic sequences of operations with material flow, with information and documents can be represented as vector-scalar components, being representation of elements of vector chain.

Vector part of three horizontally and vertically interconnected logistic flows characterizes a direction. Material flow and generated by it the informative and documentary flows carry the sign of vector structure (direction, addressee), as well as quantitative sign (magnitude of flow, expressed in the proper units of measuring).

The vector constituent of logistic flows is integrated with temporal sizes also, that is it is communicated with the time of implementations of operations in every logistic flow and time of expectation of implementation of subsequent operations on a horizontal line $\left\{ \xrightarrow{t_{exp}} \right\}$ and vertical line $\left\{ \begin{array}{l} t_{i\ exp} \uparrow \\ \downarrow t_{i\ exp} \end{array} \right\}$.

In the parameters of time of implementation of operations and time of the interruptions caused by horizontal and vertical communications a Vector-scalar model can be represented in a formalized form for the whole chain of material traffic.

However, the solving of concrete task of formalization of process of material traffic in TFC allows to be restricted to examination of the model of the leading module. In this case the model of the leading module in the parameters of time of t_{tech} and t_{texp} ($\sum$ T), conditioned by horizontal and vertical communications of logistic chain, acquires a form:

$$\begin{array}{lcl} a_{i=1} \rightarrow & a_i \xrightarrow{\sum t} & a_{i+1} \\ & t_{ni} \downarrow & \\ & \uparrow t'_{ni} & \\ u_{i=1} \rightarrow & u_i \xrightarrow{\sum t'_i} & u_{i+1} \\ & t'_{ni} \downarrow & \\ & \uparrow t''_{ni} & \\ q_{i=1} \rightarrow & q_i \xrightarrow{\sum t''_i} & q_{i+1} \end{array} \qquad (8)$$

In accordance with the expression (8) the time of expectation of implementation of operations on every chain of material traffic except for the expectations caused by engaged condition of servicing devices on a horizontal line, takes into account interruptions (outages) because of the vertical communications between operations of logistic flows. Every logistic flow includes the number of operations which in the parameters of time make the following magnitudes:

$$\begin{aligned} &\sum_{i=1}^{n}(t_{i\ tech} + t_{i\,exp}) = T_a \\ &\sum_{j=1}^{k}(t'_{j\ tech} + t'_{j\,exp}) = T_u \\ &\sum_{\xi=1}^{l}(t''_{\xi tech} + t''_{\xi\,exp}) = T_g \end{aligned} \qquad (9)$$

where T_a – general duration of material traffic in the examined logistic chain; T_u – general duration (taking into account expectations and interruptions on vertical communications) of processing, traffic and reception of information conformably to the chain of material traffic; T_g – general duration (taking into account expectations and interruptions to vertical communications) of reception, drafting and exchange of technological, commercial and other documentation.

Accordingly (9) the logistic norm of stay of the freight in the leading module is the magnitude of time (*Ti*):

$$T_i = \max\begin{Bmatrix} T_{ai} \\ T_{ui} \\ T_{g\xi} \end{Bmatrix} \qquad (10)$$

Determination of temporal indexes of cargo (T_{ai}), informative (T_{ui}) and documentary (T_g) flows at different variants of functioning of the module will allow to set the optimum duration of advancement of the freight, which will be taken as a technological norm for the chain of material traffic in TFC.

The examined logistic chain of material traffic at interaction of production and transport is characterized to that in its structure there is the leading module which is functioning in intercommunication with the previous and subsequent modules. Let us represent this chain as sequence of the modules (M_n) where the leading module is a member:

$$M_1, M_2...., M_n \tag{11}$$

where: n – number of the modules in a logistic chain.

As logistic flows in the chain of material traffic are characterized by the fortuity character (randomness) of parameters which at every moment of time adopt a certain value with the known degree of probability, that is they have a stochastic character of conducting, it is possible to consider the leading module as a system of the following form:

$$S = \{M_b; x_i(t); y_i(t)\} \tag{12}$$

Loading (number of requests) on the leading module as the material flow of $x_1, x_2 ., x_n$ or in the kind of information $U_1, U_2 ., U_n$ as well as the flow of documents of $q_1, q_{2...}, q_n$ can be set for the module M(S) in a form:

$$\begin{aligned} x_i^s &= (t, x_1, t \cdot x_2, ..., x_n) \\ u_i^s &= (t, u_1, t \cdot u_2, ..., u_n) \\ q_i^s &= (t, q_1, t \cdot q_2, ..., q_n) \end{aligned} \tag{13}$$

It can be done thus, both in a quantitative form, and in a form of distribution laws of x_i^s, u_i^s, q_i^s. Thus, attending device of the module (M_b) is characterized by the number of attendant channels and their capacity.

Consequently, the decision of question of providing of effective interaction of the leading module with the interconnected modules consists in identification of its input and output parameters, and the mathematical modeling is the basic method of researches, as most complete answering decision to the stated task.

The flowing process in the examined modules is differentiated to a great extent. In it continuous regular operations are passing to discrete operations which the elements of irregularity and stochastic are inherent to. In this connection the process of material traffic is found under action of sufficiently great number of influencing factors and in this case use of analytical model with a strict mathematical chart, with the system of algebraic and differential equalizations and limitations on variables cannot reflect the real process and its communications with sufficient completeness and truth, and also to set the preset parameters.

In a greater measure the mathematical model of task of mass service answers the requirements of this article, basic data for the decision of which can be received directly from the analysis of process of material traffic in the modules [3, 6].

The models of mass service are widely used for the determination of parameters of transport flows at the computation of processing capacity of the railway stations, processes of functioning of freight fronts and storages, processes of production of material and technical supply, marketing and sale of products and others.

Possibilities of the use of model of mass service broaden substantially with application for their realization of methods of statistic tests and imitation simulation on the basis of computer technologies.

4. VERIFICATION OF METHOD, MODEL AND ALGORITHM FOR THE DECISION OF PRACTICAL TASKS

The offered method, model and algorithm, allow to form the logistic chain of material traffic in various TFC of industrial enterprises.

Similar task with forming, modeling and optimization of chain of material traffic in the TFC «rolling-mill shop - transport» was solved for the big iron-and-steel plant of Ukraine. On the results the researches, the duration of processing of the EP carriages at the doubled operations was cut down in the TFC more than 3 hours and the considerable reduction of the costs of transportation is attained [7].

5. CONCLUSIONS

1. In the conditions of instability of rhythm of work of production and transport of enterprises community of production interests of participants of the process of material traffic creates opportunity of their new integration in the logistic system within the framework of the TFC.

2. The feature of the material conducting flow of the TFC consists in its phase transformation (train flow ↔car flow ↔freight traffic ↔ material traffic), and the leading link of chain is the phase of the freight traffic and module realizing its function.

3. The control by micro flowing process is carried out on a leading link (the module), and as a criterion of management is taken a logistic norm determining duration of its technological operations, synchronized with motion of documentary (informative) flow.

4. The task of control by micro flowing process of the TFC is solved on the basis of the offered method and consists in forming of chain of material traffic, identification of input and output parameters of flow in the leading module and their optimization with the use of models of mass service.

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