logistical system; material traffic chain;
transportation-and-handling complex

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DESIGNING OF LOGISTICAL CHAINS INSIDE PRODUCTION AND TRANSPORT SYSTEM OF METALLURGICAL ENTERPRISE

Summary. Existing systems of transportation service of metallurgical enterprises are considered and the need for logistical management of production-and-transport system of enterprises is substantiated. For this purpose principles of development of logistical chains that provide efficiency in interaction between production and transport are worked out.

ФОРМИРОВАНИЕ ЛОГИСТИЧЕСКИХ ЦЕПЕЙ В ПРОИЗВОДСТВЕННО-ТРАНСПОРТНОЙ СИСТЕМЕ МЕТАЛЛУРГИЧЕСКОГО ПРЕДПРИЯТИЯ

Аннотация. Рассмотрены существующие системы транспортного обслуживания металлургических предприятий, а также обоснована необходимость в логистических принципах управления производственно-транспортными системами предприятий. С этой целью разработаны принципы формирования логистических цепей, обеспечивающих эффективность взаимодействия производства и транспорта.

1. INTRODUCTION

Transport is an integral part of logistical systems. It also participates in logistical systems development.

Logistics of transportation as a branch of knowledge has two areas of focus. The first one concerns supply chains within macro-logistical systems. The second one concerns material traffic chains within industrial enterprises (micro-flowing processes) – in this case we deal with logistics of transportation inside industrial enterprises.

Logistical issues of internal transportations, and primarily their scientific base, are developed insufficiently. This affects negatively the production-and-transport systems of enterprises.

Large-scale machine-building and metallurgical enterprises output can reach 5-6 million tons per year. The pathway of material traffic inside these enterprises (from receiving of raw materials to finished products shipment) necessarily includes in its structure transport links. Here railway transport plays a leading part. On the one hand it interacts with arterial railway and on the other hand it is directly involved in manufacturing process.

In this context metallurgical enterprises incorporate two types of railway transport subsystems. The first type refers to external transportations. External industrial transport brings raw materials to the enterprise and carries finished products from its premises either to warehouse terminals or directly to a purchaser. The system of external transportations provides handling of freight cars that belong to external owners.

The second type refers to internal technological transportations using freight cars that belong to the enterprise. Internal industrial transport is used inside the enterprise and provides transportation service of manufacturing process.

External transportations are carried out in different rhythms of production and transport operation. It happens due to the following reasons:

- irregularity of raw materials supply;
- lack of sufficient stock of raw materials of required quality;
- varying intervals between inbound unit trains with raw materials;

varying output;

- a big number of operating carriers, etc.

Within the system of external transportations the problem points are:

- the point of interaction between transport and unloading complexes in the process of receiving of raw materials;
- the point of interaction between transport and production shops in the process of finished products shipment.

Here measurable idle time of both rolling stock and handling facilities occurs.

In a number of instances (especially in winter when it is necessary to heat up frozen goods inside freight cars) utilization of technical facilities of freight station can reach 90-95% and, as a result, their work is being blocked for a certain period. At the same time the main handling facilities – the car dumpers – are utilized only by 50-55% of their overall operation time.

After being unloaded 45-50% of inbound freight cars are delivered to rolling mills. Here, under the conditions of existing system of finished products shipment, additional idle time occurs. This idle time is caused by the following factors:

- overdue metal products;
- overdue shipping documents;
- reservation of rolling stock.

In the present situation an average duration of cars stay inside the enterprise accounts for 30-35 hours whereas factual time of cars stay inside the enterprise reaches 50-60 hours. Therewith up to 66-70% of overall time of freight cars handling falls at loading and unloading complexes. Hence transportation costs and production losses are significantly increasing.

Internal technological transportations are complicated by pulsating rhythm of production facilities operation. Such a rhythm is conditional upon frequent variance of production facilities output, leads to a change in freight traffic between them and is characterized by significant irregularity.

Furthermore internal technological transportations are complicated by the following factors:

- firstly, – deficiency of storage facilities for a short-term storage of products of melting (a consequence, products of melting are directly loaded into the rolling stock);
- secondly, – unregulated intervals between tapping (or cast) that exclude possibility to bring under regulation the beginning and the ending of freight operations.

In this connection ill-timed providing of production facilities with freight cars leads to measurable losses of products. For example, the losses of blast-furnace process total up to 120-150 thou tons year. In a number of instances violation of schedule of transport service of production facility can lead to its stoppage.

To manage the growth in production, reservation of transport facilities that considers the highest level of irregularity is carried out. Besides, additional technical facilities of freight stations that provide transport service of production facilities are implemented.

Owing to lack of coordination between freight operations on the one hand and transport operations on the other hand operative supervision of the material traffic chains isn't feasible.

Conservative method of control of technological transportations that bases on operating schedule makes it possible to reconcile the discordance of rhythm of production facilities operation. Still this can be achieved one-sidedly, utilizing only technical reserves of transport that eventually results into additional transportation costs and growth in metal products cost.

The experience of large-scale metallurgical enterprises shows that there is no high efficiency of interaction between production and transport using principles of the abovementioned conservative method of control (in these circumstances, the failures of manufacturing process are not excluded). The analysis has shown that fulfilling of operating schedules does not exceed 40-50 %.

Due to the abovementioned, we can make a conclusion that enhancing efficiency of interaction between production and transport within the enterprise at this time is an extremely important issue. It should be resolved using new technological base and information system that provide continuity of manufacturing process. New approach is based on logistical principles and implies the unity of interests (i.e. technical, technological and organizational interoperability) of all production process participants. Unity of interests, in its turn, involves obtainment of overall financial result (that is profit).

However, neither production on the one hand nor industrial transport on the other hand technically are not ready for resolving this problem because the range of related issues is still highlighted, analyzed and developed insufficiently.

2. LITERATURE REVIEW

Issues of interaction between production and transport within enterprises have been attracting the attention of researchers for quite a long period. Initially interaction between production and transport was considered under specific conditions, without regard of processes dynamics of production and transport operation. Further analysis was related to development of methods of optimization of internal freight cars traffic with the purpose of its adaptation for the rhythmic discordance of production facilities (production shops) operation. The result of this analysis became development and implementation of operational schedules for production and transport of enterprises.

Necessity in further improvement of methods of optimization of internal freight cars traffic led to development of a number of conceptually new solutions.

In the paper [3] a new approach for solution of the problem is offered. The paper notes that one-sided understanding of interaction between production and transport (in cases when transport adjusts itself to production) has exhausted itself. Placing emphasis on activation of the production capability allows achieving much more significant economic benefits.

Further development of this approach was carried out in the paper [10]. The paper suggests optimization of interaction between production and transport basing on implementation of adaptive structure of transport system. In such a case, parameters of technical facilities inside the points of interaction – ‘Transport - Production’ – are determined in combination with optimal dynamics of the technological process of finished products manufacturing.

Along with the abovementioned, there are a number of recent publications that associate the enhancing of interaction between production and transport with adopting of logistical principles.

The paper [9] considers intra-logistical issues and defines an extremely important role of transport in the processes of reliable functioning of the whole logistical system of an enterprise. Reliable functioning of the logistical system is related to the necessity in synchronization of material and information flows.

The paper [11] defines the functions of industrial transport within intra-logistical systems of enterprises. Here logistical systems of both transport and production are identified through their functional features: logistical systems of transport provide connection between consignor (the enterprise) and consignee by means of the main transport; logistical systems of production provide inter-shop transportations of raw materials, fuels, semi-finished products, etc.

The paper [5] in general terms considers issues of management of a hierarchical system of transport service of production facilities under the conditions of multistep technological process of manufacturing of finished products. The paper emphasizes the necessity of assessment of the impact of technological parameters of the transport service on the production performance.

There are a certain number of papers published abroad that concern issues of implementation of logistics, as a factor of production development in terms of free market economy and competitive environment.

Basing on the results of our analysis [7, 12] we can make a conclusion that the most efficient way of activation of production and transport interaction, is an adoption of logistical principles of management and control of production-and-transport systems of enterprises.

The purpose of logistical management of such systems is the structural arrangement of essential synergetic connections between its subsystems – hence the system acquires its properties of emergence. It is necessary to emphasize that according to optimization theory, logistical management implies system integration that allows achieving much higher economic results (in contrast to segmentary management of specific functions) [2].

3. OBJECT OF THE STUDY

The article addresses principles of development of logistical chains inside production-and-transport systems of enterprises.

Metallurgical plant that represents production of high complexity was adopted as a survey item.

4. THE MAIN PRINCIPLES OF DESIGNING OF MATERIAL TRAFFIC CHAINS INSIDE LOGISTICAL TRANSPORTATION-AND-HANDLING COMPLEXES

Solution of the abovementioned problem is based on systems concept. The system approach implies structuring of elements of a system along with establishment of connections between these elements basing on structural model of production-and-transport system of enterprise. While developing the structural model the following baseline information was taken into consideration: process flow sheet of rolled metal manufacturing; list of production units and connections between them that define trajectories of material traffic; process regulations and standards of production units operation; list of main and accompanying inbound and outbound material flows. The structural model of the Metallurgical plant in the general non-strict form is presented on fig. 1.

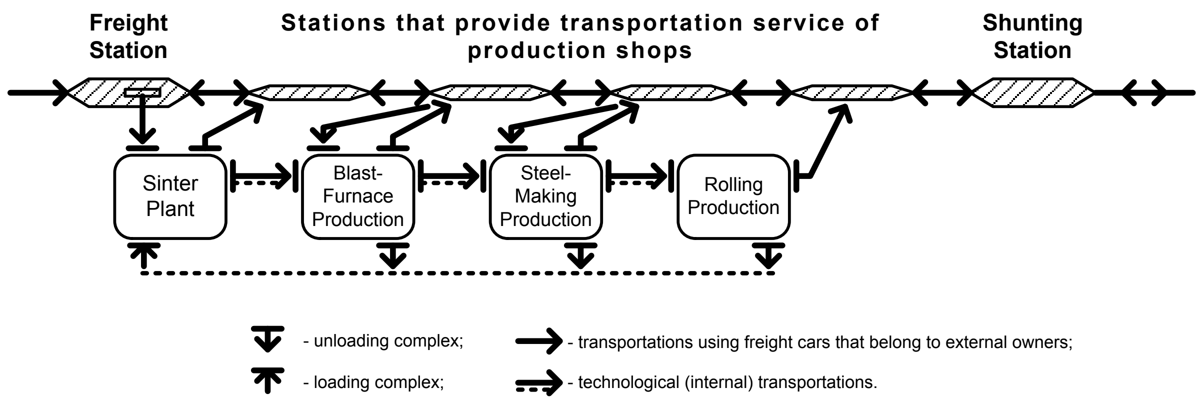

Fig. 1. Scheme of production-and transport system of metallurgical enterprise
Рис. 1. Схема производственно-транспортной системы металлургического комбината

According to the model, production process of the enterprise follows the technological steps sequence “Warehouse – Production Unit – Warehouse” or “$S_i - A_i - S_{i+1}$”. Such a structure allows describing the production process fairly easy using relatively simple mathematics.

The model analysis shows that material traffic functionally integrates process stages, production units and warehouses in a single production system of the enterprise. Material traffic consists of the three separate groups of material flows that carry out the following functions:

- raw materials supply;
- finished products shipment;
- technological transportations integrated into production process (burden material supply of production units, transportations of products of smelting, transportations of metal-containing wastes).

The abovementioned flows of freights have predominantly constant volumes and addressness, that is defined by planned production volumes.

Functional decomposition of material traffic allows identification of the abovementioned flows by their most important characteristics: type of freight, type and ownership of rolling stock, regulations of transportations, transport technology structure, availability of information that accompanies a freight, availability of information concerning the transportation management system.

Basing on results of conducted analysis, the points of interaction between production and transport are being distinguished by the abovementioned functional characteristics inside material traffic chains. These points should be focused on as logistical complexes or subsystems of logistical production-and-transport system of the enterprise.

To such systems, the following ones refer:

- logistical transportation-and-handling complexes (LTHC). These are designed for receiving and unloading of raw materials that are delivered from the arterial railway, as well as for shipping of finished products to the consumers.

There are some peculiarities of such complexes operation:

- handling of freight cars that belong to external owners;
- after unloading operations are completed some empty freight cars are used for loading operations;
- inextricably linked material and information flows.

- logistical transportation-and-technological complexes (LTTC). These are designed for fulfillment of technological transportations between production areas (blast-furnace, steel-making and rolling shops), i.e. directly related to manufacturing process.

There are also some peculiarities of such complexes operation:

- tight relation between loading and unloading operations and production facilities schedule;
- wide range of goods with different physical and mechanical properties (molten metal and slag, hot slabs, manufacturing wastes, etc.);
- using of specialized rolling stock that belongs to the enterprise.

Economical benefits at LTHC and LTTC can be achieved by means of enhancing efficiency of all participants of the material traffic chain, including production and transport.

Results of conducted research are taken as a basis in development of a method of designing of material traffic chains inside logistical transportation-and-handling complexes.

This article provides main principles of the method of designing of material traffic chains inside logistical transportation-and-handling complexes (LTHC). They are developed basing on decomposition of freight handling process and imply the following concepts.

1. LTHC represents a constantly functioning technological subsystem of the enterprise. LTHC fulfills receiving and unloading of raw materials as well as shipping of finished products to the consumers. The systematically important element of material traffic is material flow.

Peculiarity of such subsystem lies in its multiphase structure: material flow transforms under the influence of separate servicing phases, and each phase carries out its assigned functions. Phase integration into technological system provides fulfillment of the complete cycle of material flow servicing according to the rate that production facilities define.

Inside each phase material flow maintenance method represents technologically complete group of operations that are incorporated into separate technological unit (phase). Each unit is equipped with required technical facilities.

Hence, at each phase material flow (freight) can be specified by the set of characteristics including: material traffic rate, freight properties (weight, volume, outline dimensions, physical and chemical characteristics, etc.), as well as package properties and service conditions. These characteristics change at each phase: the freight condition transforms into the pre-set one that meets requirements either of the manufacturing process (during receiving of raw materials), or transportation to the arterial railway (during shipping of finished products).

It is obvious from the above mentioned that the freight condition goes through qualitative changes within the cycle of phases within material traffic chain in LTHC.

Thereupon concerning the material traffic chain, in contradistinction to a definition of “flow” that corresponds to a definition of “technology”, it is reasonable to introduce a definition of “flowing process” that corresponds to a definition of “technological process”.

As is known, flow can be described by three parameters; at the same time flowing process can be described by four parameters, these are: quantitative parameter (Mg, m3), time parameter (min, h), spatial parameter (km) and, it is ought to be emphasized, – phase parameter that defines qualitative freight condition.

Hence, qualitative transformation of freight condition can be interpreted as increase in working assets that can be estimated through cost parameters.

2. In the context of industrial enterprises operation, interrelations between production shops, or between production shops and transport, do not stipulate for commodity-money relations (i.e., there is no flow of funds) and depend on general economic effect. Whereupon, the flowing process of material traffic involves only material and information flows. The last one includes, on the one hand, the data for drafting of production and transportation documents using predominantly hard copies, and, on the other hand, the data that allows management of material traffic using computer media. The necessity in information processing technologies gives grounds for consideration of information transfer as additional increase in working assets that can be estimated through cost parameters.

Therefore, material traffic chain of LTHC can be represented as a dual-layer process that moves within single cycle of phases of material and information flows. Material and information flows are separated through time and space and are characterized by different structure of their component flowing processes, whereas the flowing model of working assets is taken as a unifying framework.

It is obvious from the abovementioned, that optimization of dual-layer process within the framework of phase cycle of LTHC should be carried out through parameters of material and information flowing processes: first and foremost, basing on synchronization of these flowing processes through time; second, basing on their interrelation.

3. Transportation-and-handling process of production facilities of enterprises involves a principal unit. Handling capacity of this unit is determined according to parameters of technological process of production facilities and, as a rule, has no reservations. Cooperation between the principal unit and the adjoining ones allows ordering a single rhythm of production and transport, and reducing deviations in pre-set parameters of the principal unit.

We can make a conclusion that the phase where direct processing of the freight is carried out can be accepted as the principle unit within the framework of phase cycle of LTHC. This unit carries out complex of the main handling regimented operations. Here qualitative characteristics of the freight are brought up to the required ones.

It is necessary to emphasize that exactly these phases are the coupling points between macro-logistical supply chains and intra-logistical material traffic chains.

4. In up-to-date conditions production and transport operate in different rhythms at metallurgical enterprises. That is why, to increase efficiency of interaction between production and transport the main tool becomes control of dual-layer process within LTHC.

Under the terms of metallurgical enterprise, control of flowing processes is carried out at three levels: management of freight trains, management of groups of freight cars and management of freight traffic. For transport technology optimization the first two levels are enough.

While solving a problem of enhancing efficiency of interaction between production and transport, management of freight traffic comes to the fore. As is known, when a freight goes through LTHC it is subject to certain technological processing that takes restricted time (t_r). After these operations are completed standby time occurs (t_s).

These two items make up the whole time of freight stay inside LTHC (t):

$$t = \sum t_r + \sum t_s \tag{1}$$

Management of freight traffic provides reducing of the standby (idle) time during transportation service of production shops. The reasons that cause the idle time are: unreadiness of production for raw materials receiving, lack of finished products of required quantity and quality, unpreparedness of commercial documentation. Reasons related to transportation are predominantly caused by delays in delivery of rolling stock.

The analysis of material traffic chain of LTHC shows that rhythmic discordance of production and transport operation is focused in the principle unit. However, management of freight traffic can make a new effect by the means of redistribution of technological functions of the principle unit. Redistribution of functions implies transfer of accumulative and accommodating functions to the adjoining links, as well as transformation or substitution of dynamic functions with static ones and vice versa [4].

As a criterion of material traffic control within LTHC should be accepted the duration of dual-layer process in the principal unit.

Presented concepts form the methodological base for designing of material traffic chains inside LTHC.

Models of material traffic chains inside LTHC of metallurgical enterprises are presented on fig. 2 [7].

The presented models show the phase structure of material traffic inside LTHC.

Phase structure of LTHC of receiving of raw materials incorporates the following phases: “Freight Trains Traffic” (this phase fulfills safety and commercial inspections of unit trains), “Groups of Freight Cars Traffic” (this phase carries out separation of trains into arranged groups of freight cars), “Freight Handling” (this phase carries out unloading operations via car-dumpers) and “Raw Materials Flow” (the supply of raw materials to the bedding yards for processing).

Phase structure of LTHC of finished products shipment incorporates the following phases: “Metal Products Flow” (the completion of rolling and quality control), “Freight Handling” (this phase carries out shipping of rolled steel at the transportation-and-forwarding site of the rolling mill), “Groups of Freight Cars Traffic” (this phase carries out assembling of arranged groups of freight cars into unit trains) and “Freight Trains Traffic” (this phase fulfills dispatching of unit trains to the external railway net). Therefore, in both instances the phase “Freight Handling” (where unloading and loading operations respectively takes place) fulfills functions of principal unit (phase).

The dual-layer process can be described by a set of vector and scalar components that are combined into the concerned logistical chain:

$$\left.\begin{array}{ccccc} a_1 \to \ldots \to & a_k & \to \ldots \to & a_m \\ \updownarrow & \updownarrow & & \updownarrow \\ u_1 \to \ldots \to & u_k & \to \ldots \to & u_m \end{array}\right\} \tag{2}$$

System approach defines the general purpose of designing and optimization of material traffic chains inside LTHC of metallurgical enterprise.

The subject matter of logistical optimization is as follows. Let us assume that logistical system incorporates m of units (links) x, each of which is characterized by specific technological mode. Let us introduce the following designations.

$X = \{x_1,\ldots,x_k,\ldots,x_m\}$ – a set of links of material traffic chain, where x is a principal one;

k – technological mode of the process within the principal link that can be described by the parameters t_k, s_k, c_k and ϕ_k;

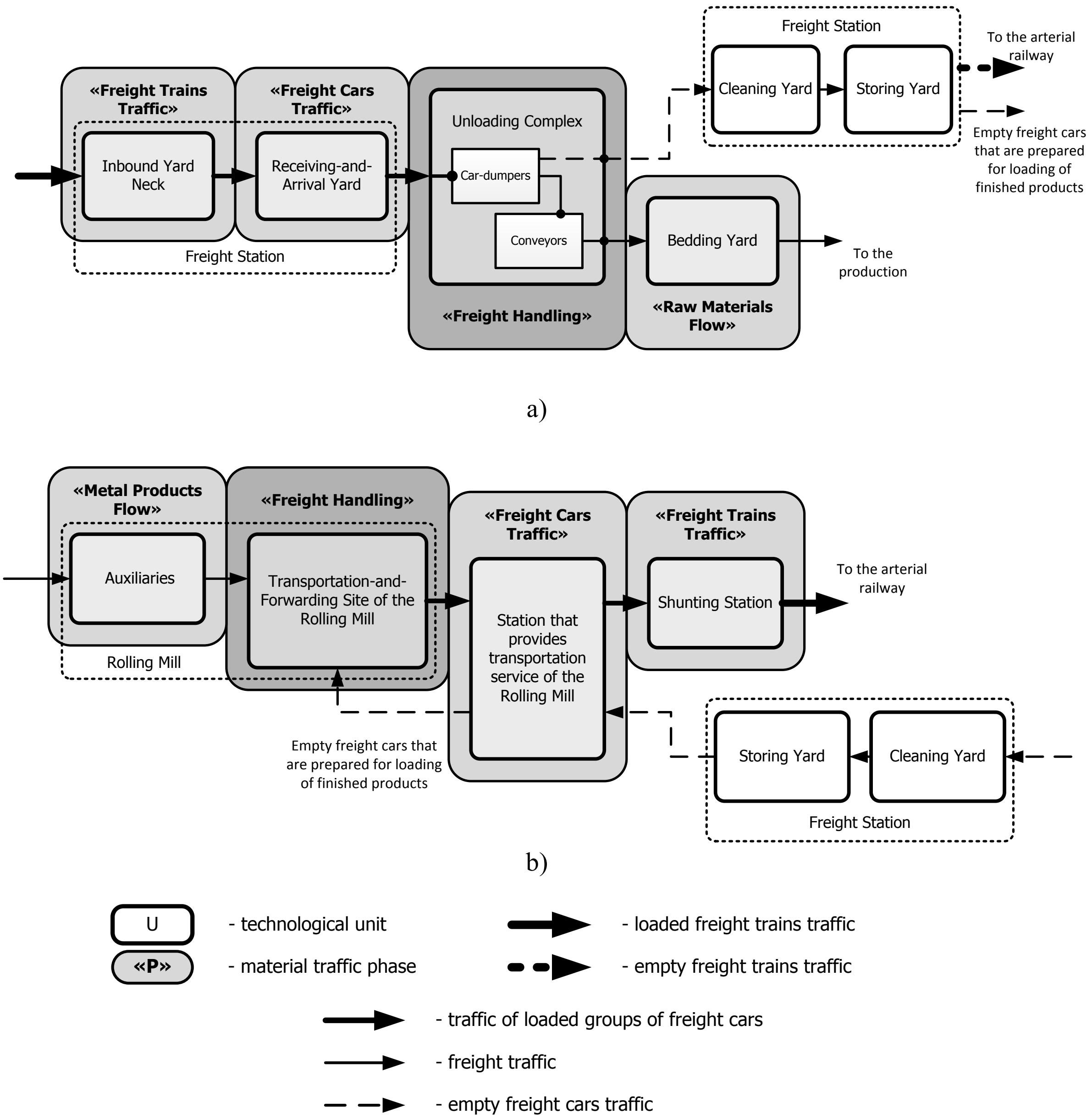

Fig. 2. Models of material traffic chains inside LTHC: a) receiving of raw materials (Sinter Plant); b) finished products shipment (Rolling Mill)

Рис. 2. Модели цепей материалодвижения в ЛТГК: a) приём сырья (аглофабрика); b) отгрузка готовой продукции (прокатный цех)

t_k, s_k, c_k, ϕ_k – respectively time parameter, spatial parameter, quantitative parameter and phase parameter. Thus:

$$x_k = (t_k, s_k, c_k, \phi_k) \tag{3}$$

The set of quantifiable parameters (s_k, c_k, ϕ_k) can be narrowed down to the parameter that characterizes the duration of operations $T(x_k)$ within the principal link – t_k:

$$T(x_k) = f(s_k, c_k, \phi_k) \Rightarrow T(x_k) = f(t_k) \tag{4}$$

As an optimization criterion the minimum duration of dual-layer process within the principal link of material traffic chain inside LTHC was adopted ($t_k \to \min$).

Consequently, the objective function of optimization of material traffic chains inside LTHC takes the form:

$$T(x_k) = f\begin{Bmatrix} [s_k^{MP}, c_k^{MP}, \varphi_k^{MP}] \\ [s_k^{IP}, c_k^{IP}, \varphi_k^{IP}] \end{Bmatrix} = f\begin{Bmatrix} t_k^{MP} \\ t_k^{IP} \end{Bmatrix} \to \min$$

$$x_k \in X \qquad (5)$$

$$t_k^{IP} \le t_k^{MP}$$

$s_k^{MP}, c_k^{MP}, \varphi_k^{MP}$ – respectively spatial, quantitative and phase parameters of material flowing process within the principal link k of material traffic chain inside LTHC;

$s_k^{IP}, c_k^{IP}, \varphi_k^{IP}$ – respectively spatial, quantitative and phase parameters of information flowing process within the principal link k of material traffic chain inside LTHC;

t_k^{MP} and t_k^{IP} – respectively, time parameters of material and information flowing processes within the principal link k of material traffic chain inside LTHC.

Organizing of an effective operation of the principal link within material traffic chain inside LTHC lies in the identification of parameters of inbound and outbound flowing processes. The main tool of the analysis is mathematic simulation as the most fitting for resolving the problem.

Inside technological units (phases) of LTHC flowing processes are considerably varied. Here continuous and regular processes transform into discrete ones that are characterized by irregularity and stochasticity. Therefore, material traffic is influenced by a variety of factors. In such conditions, use of analytical model with strict mathematical notations, including algebraic and differential equations, as well as restrictions on arguments, isn't feasible. Thus, queuing model meets the requirements. For model solution initial data can be obtained from the direct analysis of material traffic within units.

Queuing models are widely used for determination of parameters of transport flows with a purpose of estimation of handling capacity of technical facilities of freight stations, etc. Possibilities of this model are significantly widened with Monte-Carlo method and simulation modelling.

Preliminary implementation of proposed method of designing of material traffic chains inside logistical transportation-and-handling complexes "Rolling Mill – Transport" and "Transport – Unloading Complex of Sinter Plant" in terms of a large-scale metallurgical enterprise gives grounds to conclude that the proposed method is effective one [8]. In this regard further research is carried out.

5. CONCLUSIONS

Conservative methods of control of production-and-transport systems (PTS) of metallurgical enterprises are based on one-sided utilization of transportation resources, do not provide an effective interaction between production and transport and are characterized by measurable production losses. Significant economic benefit can be achieved by means of shifting the focus to activation of production capability. It can be implemented basing on logistical principles of management of PTS (i.e. system integration of material traffic chain elements and providing of single management system). Two types of production-and-transport complexes (PTS subsystems) of metallurgical enterprises were identified: transportation-and-handling complexes (LTHC) that carry out receiving of raw materials and finished products shipment; transportation-and-technological complexes (LTTC) that carry out technological (internal) transportations between production shops.

At the first-stage of research method of designing of material traffic chains inside logistical transportation-and-handling complexes is presented.

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