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Information System for Control of Raw Material Transportation of an Iron and Steel Plant

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ABSTRACT

Today, the creation and use of powerful information systems for managing the raw material flows of a metallurgical enterprise transported by the railways allow to diminish turn-round of wagons on the house tracks of the enterprise, to reduce the stock of raw materials in wagons, to create conditions for uninterrupted production, as well as to increase the level of maturity of cross-functional interaction of divisions.

This necessitates the development of a system of rapid collection, analysis, and visualization of information on the supply of raw materials, which will act as a single information space to coordinate the actions of all parties involved. Such an information system should support decisions at both the operational and tactical levels. Operational decisions in this case include changing plans for the current period, purchasing missing volumes, redirecting raw materials to other consumers, prioritization of relevant shipments and wagons' rearrangement. Tactical level includes revision of reserve and consumption standards, elaboration of special agreements with carriers.

The objective of the study is to investigate the possibility of using an information system for controlling raw material transportation to reduce the turn-round of wagons on the house tracks of a metallurgical enterprise. The authors use general scientific methods, comparative analysis, mathematical methods.

The article studies the main functionality of such a system, presents a methodology for calculating the investment attractiveness of a project, and suggests further directions for development in the field of information interaction between enterprises and rolling stock operators.

Keywords: railway transport, information system, rolling stock, metallurgical enterprise, iron and steel plant, industrial transport, turn-round of a wagon.

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Introduction

Integrated (complete cycle) iron-and-steel plant is characterized by a significant volume of freight transportation, a large range of products and sophisticated production technology. Daily iron and steel works receive various types of cargoes: iron ore concentrate, ore, iron nuggets, fluxes, dry- and wet quenched coke, coking coal, refractory materials, equipment, and others.

The metallurgical industry makes a significant contribution to the development of the Russian economy. The share of ferrous metal industry is just under 2 % in Russia's GDP, it is about 8 % in industrial production, and 7 % in export. The industry consumes 5,3 % of all electricity and 8 % of natural gas produced. The share of ferrous metal industry freight transportation in the total volume of railway freight turnover is 15 % [1, p. 31].

In the modern context large metallurgical companies have embarked on a course of business development not only by increasing the volume of production and expanding the range of products, but also by increasing production efficiency by optimizing internal processes. As already mentioned, railway transport is the main mode of transport for the industry, therefore, optimization of the transportation technology cannot be ignored.

The delivery of raw materials for the need of ferrous metal industry and the shipment of finished products to consumers is carried out with the assistance of railway operator companies [2, p. 299]. Provision of all-purpose and specialized rolling stock for transportation takes place on the basis of a contract of freight forwarding services, which is usually concluded for 5 years and provides for a certain rate for wagon engaging. If the turnover of wagons increases above the normative value, the operator penalizes the enterprise for demurrage, on the opposite, if the turnover is lower than the normative value, the operator company can pay a premium under the terms of the contract [3, p. 265].

It is clear that with such a significant volume of freight transportation, a decrease in rolling stock turnover will give a tangible economic effect and reduce the transport component in the cost of finished products, which means that the metallurgical plant will have a competitive advantage in the market. In addition, the digitalization of the economy encourages companies to create powerful IT-systems that provide employees with complete and up-to-date information about technological processes for making optimal decisions.

This determines the *objective* of the study which is to explore the possibility of using an information system for monitoring raw material transportation to reduce turn-round of wagons on the house tracks of a metallurgical enterprise.

Results.

System purpose

Tasks

The object of automation when introducing a decision support system in the field of supply chain management of raw materials is the activity of all involved departments: supply department, logistics division and production department. The information system (IS) also provides for the construction of an interaction interface with other systems existing at the enterprise and beyond, and is intended for:

• raw material supply planning;

• development of optimal shipping schedules;

• consolidation of information on the use of the rolling stock, including that about wagons:

– loaded by the consigner;

– arrived at the enterprise;

– unloaded on the enterprise tracks;

• consolidation of information on shipments to the enterprise;

• monitoring the compliance with schedules of shipment of raw materials;

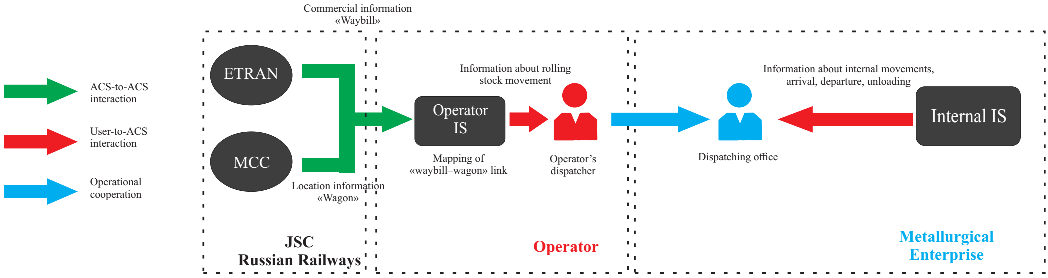
• monitoring the provision of shipment operations with empty wagons;

• monitoring movement of loaded wagons on the rail network (in our case, on the network of the JSC Russian Railways);

• forecasting the arrival of wagons with raw materials based on data on their actual location on the network;

• accounting of loaded rolling stock with raw materials on the house tracks of the enterprise during the period;

• informational support of the process of shipment of raw materials in terms of providing information on possible adjustments to the loading schedule when the number of wagons with raw materials on the house tracks of the enterprise deviates significantly from the



Pic. 1. The existing scheme of interaction.

normative value upwards or downwards, taking into account the rolling stock located on the public network;

• forecasting the balance of loaded wagons with raw materials on house tracks at the end of the reporting period.

Thus, among the main objectives of the development and implementation of the said system, it is necessary to highlight the following objectives:

• organization of automated accounting of loaded and unloaded volumes of raw materials;

• providing operational control and analysis of the provision of shipment of declared volumes of raw materials by empty rolling stock;

• exclusion of manual filling of documents to exclude errors and discrepancies;

• providing operational control of input information;

• improving the quality of planning;

• ensuring a high level of reliability and data protection;

• development of cross-functional interaction of enterprise divisions;

• reduction in the cost of engaging rolling stock by reducing the turnover of wagons.

Current system

To study the possibility of using an information system for control of raw materials in order to reduce the turnover of wagons on the house tracks of a metallurgical enterprise, it is necessary to analyze the current system revealing its advantages and disadvantages. As a result of a comparative analysis of the current state of basic theory and practices in the field of traffic control at metallurgical enterprises, the authors compiled a diagram of the existing framework if interaction between the carrier, the operator company and the enterprise (Pic. 1).

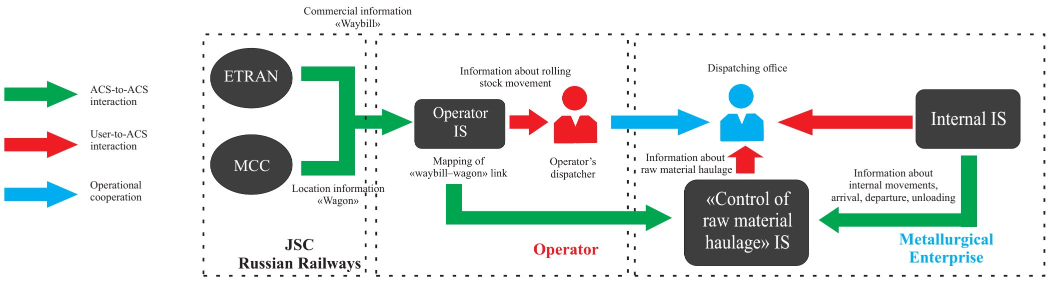
All commercial information regarding the waybill, i.e. the names of the freighted goods according to the Single Tariff and Statistical Nomenclature of Goods (ETSNG), of the consignor, of the consignee, of the destination station, the weight of the goods, is transmitted directly from the Electronic Transport Waybill (ETRAN) system. All information on the ground location, i.e. the station of location, the railway of location, the last operation, the time of the last operation, the wagon number, comes from the Main Computer Center (MCC) of Russian Railways. In the Operator IS, all received data are mapped and then the dispatcher of the operator company downloads them and transfers to the employees of the metallurgical plant. In turn, the plant's dispatching office downloads data from the internal IS and consolidates all the information necessary for decision making.

The disadvantages of the current system are the lack of access for the plant's employees to the Operator IS, the information gap between the internal and external transportation control systems, the great influence of the human factor, which inevitably leads to errors and discrepancies in the information used.

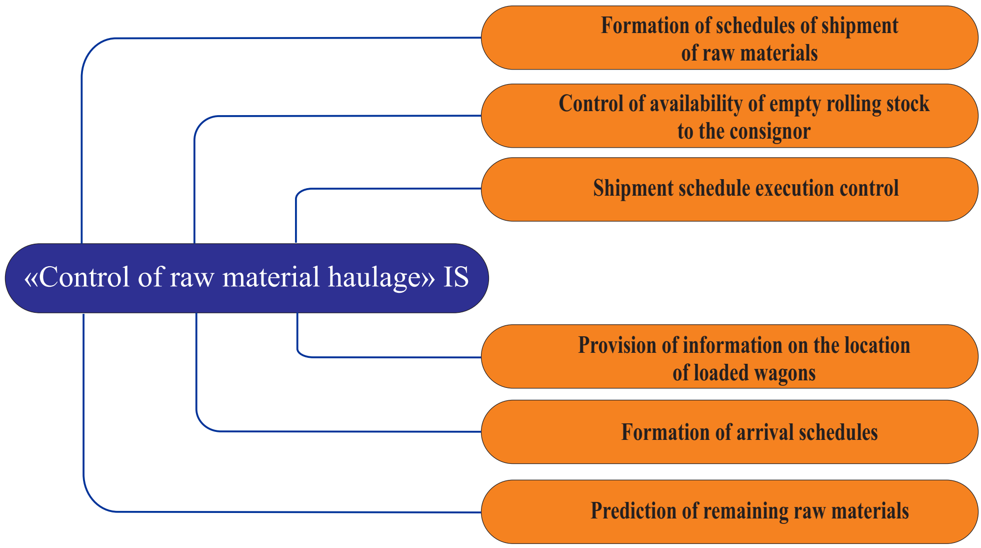
The proposed «Control of raw materials freights» IS (Pic. 2) is a link that integrates the internal and the operator systems into a single whole and allows the dispatching office (and other employees of the company) to see the entire logistics chain, while significantly reducing the amount of operational interaction with representatives of the operator company and not restricting access to the previous internal IS.

System functionality

Based on the desired goals, we can distinguish the functions that the information system should perform (Pic. 3).



Pic. 2. Proposed interaction scheme.



Pic. 3. Functions of «Control of raw materials freights» IS.

The functionality of the system allows full control over the material flow throughout the chain: «origin of freight flow»–«transportation to the consignee»–«consumption».

A) Formation of schedules of shipment of raw material

At this stage, all data necessary for optimal shipment schedules should be entered into the system. The following should be taken into account: the planned volume of transportation of each type of freight and for each consignor, shipping type, the type of rolling stock, the production capacity of the consignor and the consignee, standard delivery time, application numbers for freight transportation (i.e., form GU-12). Depending on the type of raw material, its shipment should be planned either on certain days (if the freight is to arrive at the metallurgical plant on a specific date), or so that to ensure a uniform delivery of raw materials during the accounting period taking into account the delivery time.

After that, the obtained schedule is subject to coordination with all involved divisions both in the metallurgical enterprise, and with operators of a rolling stock and suppliers of raw materials. The agreed and approved shipment schedule is «uploaded» in the IS for subsequent shipment accounting.

It should be noted that the Information System «Control of raw material haulage» should provide for the possibility of adjusting the shipment plan.

B) Control of availability of empty rolling stock to the consignor

Constant monitoring of the availability of rolling stock to suppliers is possible only on the basis of information interaction between the operator company and the metallurgical enterprise in «Automated control system to Automated control system» mode (ACS-to-ACS) and should allow to determine in advance the risks of breaking the schedule due to the lack of wagons at the consignor's side.

Data on the available rolling stock on the consignor's house tracks and at the junction station are transmitted from the Operator IS. In the presence of approaching empty wagons the « Control of raw material haulage» IS automatically predicts the date of arrival to the consignor.

Shipment is considered secured if:

$$m_{sender} + m_{j.st} + m_{coming} \geq m_{planned}, \quad (1)$$

where m_{sender} is the number of wagons on the consignor's house tracks;

$m_{j.st}$ is the number of wagons at the junction station;

m_{coming} is the number of wagons that will arrive by the specified date;

$m_{planned}$ is the number of wagons planned for loading.

Otherwise, the system signals the risk of failure of the shipment plan with a color-coded indication.

C) Shipment schedule execution control

Information on shipment of each type of freight and each consignor is received for the calculated previous railway day after 18:00. Information can be transmitted either directly from the Electronic Transport Waybill (ETRAN) system or indirectly from the Operator IS. The obtained values are compared with the planned indicators, and all discrepancies upward and downward are indicated by a certain color.

D) Provision of information on the location of loaded wagons

The information transmitted from the Operator IS must contain the following attributes:

- the name of the railway of location;
- the name of the station of location;
- the name of the departure station;
- the name of the last operation;
- the date of the last operation;
- the train index;
- the wagon number;
- the waybill number;
- the name of the destination station;
- distance to the destination station from the location;
- the name of the consignor;
- the name of the consignee;
- empty or loaded wagon indication;
- the name of the type of rolling stock;
- the name of freight according to the Unified Tariff and Statistical Nomenclature of Goods;
- the weight according to the waybill;
- the date of departure.

Based on the above data, the predicted arrival time is automatically determined. It can be determined, firstly, as the average of historical data on the arrival of each type of raw material for the previous period, and secondly, by calculation on the basis of regulatory documents (order of the Russian Ministry of Transport No. 245 dated 07.08.2015 «On approval of the Rules for calculating the time of delivery of goods, and of empty freight wagons by rail» [4]). In the first case, it is necessary to first analyze the information about the movement of loaded wagons within the railway network, in the second case, the «Shipment type» attribute should be added to the transmitted information, so that the system can distinguish between single wagon, grouped and route deliveries for the correct choice of daily mileage. In both cases, seasonality of transportation (summer and winter periods) should be considered.

At present, there are also other approached to predicting the arrival time, which were described in the publications [5, p. 120; 6, p. 74].

E) Formation of arrival schedules

The arrival schedule is automatically generated based on the approved shipment schedule. The date of arrival for each freight and consignor is then determined as:

$$t^i_{arrival} = t^i_{shipment} + t^i_{delivery}, \quad (2)$$

where $t^i_{arrival}$ is the date of arrival of the *i*-th freight at the metallurgical enterprise;

$t^i_{shipment}$ is the date of shipment of the *i*-th freight by the consignor;

$t^i_{delivery}$ is standard delivery time of the *i*-th freight.

If the freight is to cross the border, then one more day should be added to the obtained time for customs operations.

The completed arrival plan should include both the volumes that have arrived and the predicted volumes, which are calculated based on data on the location of loaded wagons within the railway network. Real and predicted values should be differently imaged for ease of perception.

F) Prediction of remaining raw materials

Visualization of data on the estimated balances of raw materials (an example of calculation for a ten-day period is given in Table 1) until the end of the estimated period

Table 1

Predicted Balance Information Output Form

	Date									
	01.01	02.01	03.01	04.01	05.01	06.01	07.01	08.01	09.01	10.01
1	2	3	4	5	6	7	8	9	10	11
Balance at 00:00 (beginning of day), m_{actual}	310	289	332	311	290	205	184	227	270	249
Predicted arrival, $m_{arrival}$	64	128	64	64	0	64	128	128	64	64
Unloading, $m_{unloading}$	85	85	85	85	85	85	85	85	85	85
Balance at 00:00 (end of day), $m_{predicted}$	289	332	311	290	205	184	227	270	249	228

allows to make informed decisions to accelerate or leave loaded wagons that are within the network, shift the dates of shipment of raw materials by suppliers and reduce/increase the declared volumes of supply.

The actual balance of wagons at the beginning of the day (m_{actual}) in the «ACS-to-ACS» mode is transferred from the existing system of accounting of wagons at the enterprise. The expected arrival date of the dispatched wagons ($m_{arrival}$) is automatically calculated with the formula (2).

Due to the complexity of modeling the blast furnace smelting operation [7, p. 576] and the resulting difficulties in predicting the exact volumes of unloading over a long period, and also taking into account the relative constancy of the consumed volumes of raw material by the blast furnace plant, the expected unloading of each delivery ($m_{unloading}$) can be determined by the formula:

$$m^i_{unloading} = \frac{m^i_{ten\_days}}{10} \quad (3)$$

where $m^i_{ten\_days}$ is total unloading of the *i*-th delivery for the previous ten-day period.

Based on the values obtained the predicted balance of wagons is calculated ($m_{predicted}$):

$$m^i_{predict} = m^i_{actual} + m^i_{arrival} - m^i_{unloading}. \quad (4)$$

This information can be also graphically interpreted indicating the minimum balance of raw material for ease of perception.

Data transfer from the Operator IS and recalculation of predicted values and balances are carried out every hour. If there is a technical capability and production need, the speed of updating information should be increased.

It should be noted that the interaction of information systems of the enterprise and the operator of the rolling stock may have some difficulties in controlling the movement of wagons that are not owned by the operator company. In this case, when using the «Waybill» data array for the given registration number of the wagon, a situation may arise when the information on the past period is displayed, that is, the fact that this wagon has already carried out the transportation of any freight a few months or years ago. To avoid such situations, it is possible to exclude the automatic transfer of data on transportation in the wagons of other owners and to plan the coming wagons in manual mode. Since the bulk of the freight of metallurgical plants (98–99 %) is transported by wagons of one and the same company, this assumption will not affect the accuracy of planning and production activities of the enterprise.

Evaluation of economic effect

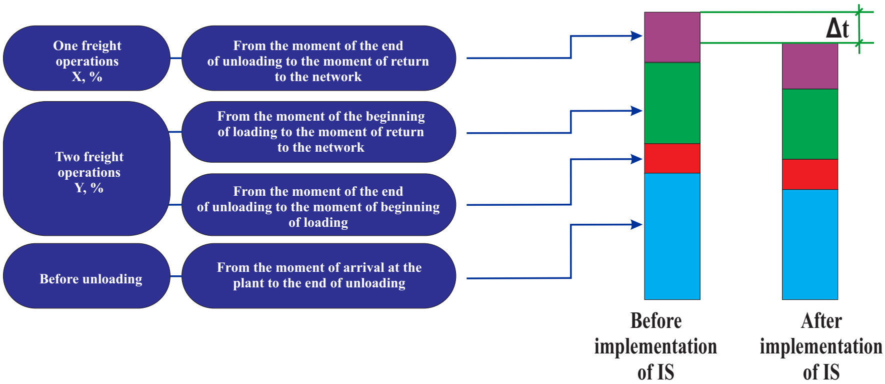
Investment attractiveness of projects and their economic efficiency are normally assessed by a set of indicators. For correct evaluation mathematical methods and comparative analysis of the proposed options are used. Many experts distinguish the net present value (NPV) as the main indicator [8, p. 113; 9, p. 557], which is the amount of cash payments resulting from the implementation of the project, reduced to the current day at the discount rate.

For the purpose of the economic assessment of the implementation project of the «Control of raw materials freight» IS, the net present value should be determined by the formula:

$$NPV = \sum_{t=1}^{T} \frac{F_{reduct} - AC_{ad.oper.costs.}}{(1+r)^t} - \frac{C_{cap.exp.}}{(1+r)^t}, \quad (5)$$

where F_{reduct} is fund flow owing to cost reduction, rub.;

$AC_{add.oper.costs.}$ means additional operating costs, rub.;



Pic. 4. Weighted average turn-round of wagon.

$C_{cap.exp}$ are capital expenditures on the project, rub.;

r is the discount rate, %;

t is number of years of expected fund flow, years.

A) Cost reduction

Improving the quality of operational cooperation of all participants in transportation, automation of monitoring of compliance with shipment schedules of raw material and monitoring the movement of the rolling stock over the network on the basis of a single information field will reduce the turnover of wagons, and hence reduce the cost of utilization of a wagon fleet. Taking into account the fact that a significant part of the rolling stock is returned empty from the plant to the network, it is advisable to use the weighted average turnover of wagons for accounting and control of the turnover of wagons on the industrial railway transport for metallurgical production (Pic. 4).

In this case, the reduction in operating costs is as follows capital expenditures:

$$F_{reduct} = n \cdot \Delta t \cdot e_{fr.wagon\text{-}hr} \cdot 365, \qquad (6)$$

where n is the average number of wagons arriving at the enterprise per day;

Δt is the decrease in turn-round of wagon, freight wagon-hour;

$e_{fr.wagon\text{-}hr}$ is the cost of 1 freight wagon-hour, rub./hour.

If fewer locomotives can be used because of implementation of the IS, then the effect obtained should be added to the savings owing to cost reduction.

The predicted decrease in the turnover of wagons on the territory of the production area after the implementation of the information system is 3–5 %.

B) Additional operating costs

In this case the additional operating costs will include the following cost items:

• depreciation cost;

• the cost of electricity consumed by the equipment;

• payment to the rolling stock operator for the provision of data, if such a service is not stipulated in the contract of freight forwarding services.

Depreciation cost is calculated by the formula:

$$DC_{depr.cost} = \frac{C_{cap.exp.} \cdot N_{depr.rate}}{100}, \qquad (7)$$

where $N_{depr.rate}$ is depreciation rate, %.

Electricity cost is as follows:

$$C_{el} = W \cdot C_{el} \cdot 24 \cdot 365, \qquad (8)$$

where C_{el} is the cost of 1 kW • h of electricity, rub.;

W is total watt-hour consumption of the equipment, kW • h.

Then:

$$AC_{add.op.cost} = DC_{depr\ cost} + C_{el} + C_{pn.opr}, \qquad (9)$$

where $C_{pn.opr}$ is the payment to the power network operator, rub.

The introduction of additional staff is not required, therefore, an increase in the salary fund is not provided.

C) Capital expenditures

Capital costs for the implementation of the decision support system will consist of the cost of server equipment and of its installation and commissioning, equipment of workplaces for employees, as well as of the purchase of licensed software (if necessary).

D) Payback period of the project

An important indicator of the economic evaluation of the project is its payback period:

the lower it is the more attractive is the investment:

$$T_{payback} = \frac{C_{cap.exp.}}{F_{reduct} - AC_{add.oper.costs}}. \qquad (10)$$

Conclusion

The implementation of the «Control of raw material haulage» IS at metallurgical enterprises will bring economic benefits thanks to the technical effects of improving the quality of operational work, making optimal schedules for the supply of raw material and monitoring implementation of these schedules, timely provision of transportation services to the plants [10, p. 66], reducing the turnover of wagons on the house tracks, ensuring a more lean time distribution of arrival of trains at the adjacent station.

It is possible to outline the main directions of further development of the system:

1) application of the system may be extended to cover of finished products (shipment, location within the network) as well;

2) increasing the accuracy of predicting the movement of material flows due to the improvement of the apparatus of mathematical modelling.

Today, under favorable conditions on the external and internal markets, large companies of ferrous metal industry of Russia are showing a steady increase in production volumes and intend to maintain this trend in the future [11, p. 19]. Hence it appears that transportation volumes will also increase, which will entail an increase in the economic effect of the introduction of the information system and a reduction in the payback period of the project.

In our opinion, the proposed methodology and the overall design of the information model can be also applied to the conditions of transport systems in other countries, subject to the necessary adaptation [12, p. 38; 13, p. 635].

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