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DESIGN OF SIMULATION MODEL FOR INTEGRATED SYSTEM OF SIDERITE TRANSPORT

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Abstract: *The article presents a model of integrated transport system for siderite, a design of the structure of this system and its verification by the help of simulation.*

Key words: *transport, system, mineral raw material, siderite, design, simulation*

1 INTRODUCTION

Simulation and integration are effective tools for intraplant transport management and therefore the submitted article deals with their combination with application of basic principles of transport logistics. By integration of several transport systems it is possible to eliminate bottlenecks in a transport process, whilst the verification of integration designs is suitable to check by simulation what is also a goal and output of this article.

2 CHARACTERISTICS OF INTEGRATED TRANSPORT SYSTEM FOR MINERAL RAW MATERIALS

Under the term integrated transport system of mineral raw materials (IDS NS) we understand time and spatially organized transport system based on the coordination of several kinds of mining transport whose goal is assurance of purposeful, economical and united transport service on the ground of mining enterprise on the part of economical and other demands of mining enterprise.

3 DESIGN OF THE STRUCTURE OF INTEGRATED SYSTEM OF MINERAL RAW MATERIALS TRANSPORT

The structure of IDS NS copies tasks which transport system is due to provide during the process of mineral raw materials processing. The structure of IDS NS is created from 3 subsystems:

- organizational subsystem, which creates legislative, planning and organizational arrangement, information service, etc.;
- transport subsystem created by transfer demands, transport networks, transfer schedules, technical base and transport conditions;
- economical subsystem which includes financing, planning, cost control related to transport, reporting of performance indexes.

The next part of the article is aimed at detailed analysis of transport subsystem of integrated system of mineral raw materials transport.

4 ANALYSIS OF THE PRESENT STATE OF TECHNOLOGICAL PROCESS AND TRANSPORT OF SIDERITE

Desing of integrated system of transport is realized for the enterprise Siderit, Ltd. Nižná Slaná which is aimed at iron ore exploitation. Iron ore is subsequently heat treated to Fe pellets which are a charge into blast furnace [9]. The next product is magnetically roasted Fe concentrate. Iron ore – siderite ($FeCO_3$) is mined by deep way on measures Manó-Gabriela and Kobeliarovo [2].
Technological process of siderite exploitation and processing is energy demanding and therefore its modernization is necessary. The level of transport control must be responsible for the level of modernization of 5 main technological nodes (exploitation and crushing, dry high-intensity magnetic separation – SVIMS, rotary furnaces, preparing plant, pelletizing). By changeover to the pit Gabriela (Fig. 1) it comes also to change of mining mechanization used by drifting and mining. There are a double-action hoisting machines of type 2B 60/ 1800 kW in the pit Gabriela. The speed of exploitation is 10 $m.s^{-1}$, the speed of drive is 6 $m.s^{-1}$. Raw ore with the specific weight 1800 $kg.m^{-3}$ is transported by pit cars type JDV 1,25 with capacity of the bed 1,25 m^3. Fig. 1 presents the hoist tower above the pit Gabriela.

In accordance with world-wide trend there were applied machines of the 3rd generation in Nižná Slaná, where reversing feeders, drag-bag winches and manual hammer drills were replaced by modern mining trackless mechanization (BBM) – container loader (PN), drilling set (VS), drilling cars (VV) from foreign producers Tamrock, JOY, Atlas Copco. After these machines were replaced by machines of domestic production of type PN 1500, PN 1700, PN 1900, PNE 1700 [3].

***Figure 1** Hoist tower above the pit Gabriela*

For unloading of free rock were applied PN by produceres Atlas Copco Wagner, type Scooptram ST-2G (Fig. 2) to the underground [10].

***Figure 2** Container loader Scooptram ST-2G*

Transport of siderite ore is realized by various transport technologies which with legislative support and technical base create transport system of mineral raw materials in the technological process of mining and processing in mining enterprise Siderit Ltd. Nižná Slaná.

5 DESIGN OF INTEGRATED SYSTEM OF SIDERITE TRANSPORT

Design of integrated system of siderite transport starts from the present state analysis of technological process and siderite transport in the enterprise Siderit, Ltd. Nižná Slaná. We accept direction of transport (raw ore exploitation, material transport) through of Gabriela pit head and existing equipments of the enterprise by the design.

We must respect these principles and demands by IDS NS creation:

- acceptance of experiences from previous operation of transport systems of mining enterprise;
- main mining transport creates the axis of transport system by operation conditions;

- to through places (terminals) enter transport systems of side mining transport; it enables creation of through nodes in which it is possible to transfer transported material to several directions;
- increase of material flow fluency within the frame of technological process of exploitation and processing of mineral raw materials, i.e. economic utilization of means of transport entering to the IDS NS;
- reduction of unproductive parallel tracks.

The base of IDS model is its structure from 5 modules:

1. *Module „Transport service of mining enterprise“* determines goals on the base of strategy setting, forecasting, planning, organization of transport.
2. *Module „Transport infrastructure of mining enterprise“* presents technotechnological capability of infrastructure and creates integrated network of transport.
3. *Module „Means of transport of mining enterprise“* presents assurance of rolling stock, transport devices and their structural elements with impletion of qualitative and quantitative indexes.
4. *Module „Operation conditions of mining enterprise“* assures transport conditions before transport, during transport and after transport by the present legislative conditions. It evaluates economic analysis and output of the module is united transport regulations.
5. *Module „Information system and technologies in mining enterprise“* is aimed at informatization of transport technologies in mining enterprise.

Interaction among all these modules is a very difficult process which is affected by many elements. Therefore it is very important to consider all elements which integrate the transport system of mineral raw materials. Design of IDS NS is affected by many factors.

6 DESIGN OF SIMULATION MODEL OF COMBINED TRANSPORT OF SIDERITE

Combination of rail transport and vertical conveying makes possible to achieve higher transfer capacity with shorter transport time and lower transportation costs in compare with transport which is created by only one transport system.
Within the frame of IDS NS solution it is possible to apply model approach as an effective tool of transport proces managing in modules 1-3. Application of model approach synthesis is possible by analytical, simulation and heuristic models. From these models we apply simulation model by transport process solution in modules 1-3. The selection of suitable programming tool for the creation of model of IDS properties was realized so that it is available and actual tool of simulation, simple and tabular by models creation, patchable with other programs (for example Excel) and also reliable. After consideration of these parameters the suitable program is „*EXTEND*“. On the present it is one of the leading computer simulation tool and it is the tool for users from various sciences. It realizes wide scale of simulations and also it provides the possibility of own libraries development. Existence of library with quite a number of ready blocks provides the creation of models [1].

Simulation model was created by support tool which makes possible to test decisions for transport process managing within the frame of modules 1 -3 in mining enterprise Siderit, Ltd. Nižná Slaná. Simulation model starts from formalized scheme of product production P_1 and P_2 set forth in [5]. Simulation model solves only the field of siderite exploitation from underground to surface to siderite processing.

6.1 Computational model of rail transport

Simulation model of rail transport is created in the program Extend and it starts from the standard STN 281713. Fig. 3 presents the computational model. The function of the model is a simulation of operation conditions of rail transport for concrete operation conditions in the enterprise Siderit Ltd. Nižná Slaná. This model makes possible to change these parameters for other operation.

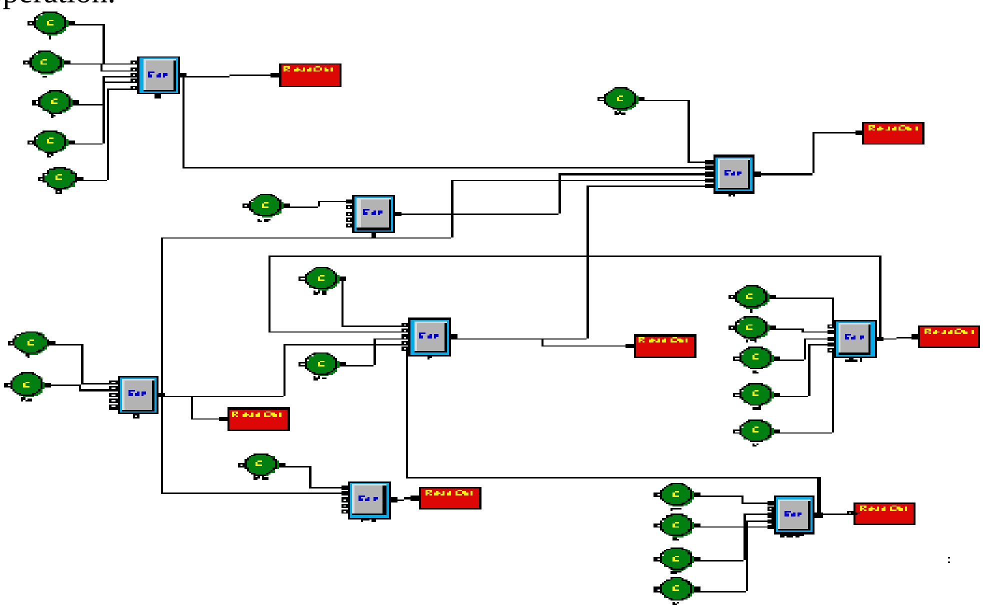

Figure 3 *Computational model of rail transport in the program Extend*

The model of rail transport is created by 4 hierarchical blocks: material transport – turn around time, necessary number of locomotives, necessary number of carriages, utilization of locomotives.

*1. Hierarchical block **„Transported material – turn around time“.*** In this part of the model it is modelled the basic function of rail transport – material transport – turn around time (Fig. 4).

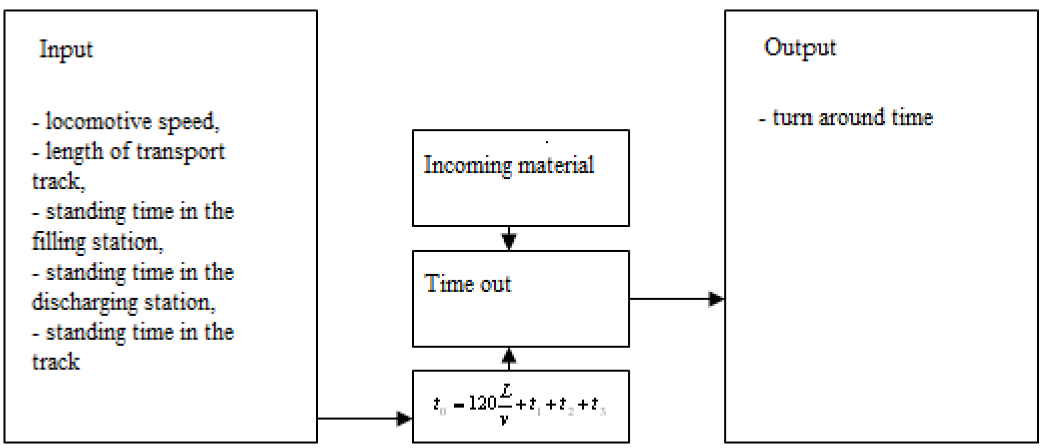

Figure 4 *Hierarchical block „Transported material – turn around time“*

*2. Hierarchical block **„Necessary number of locomotives“*** (Fig.5) starts from data which present data about the weight of daily exploitation (M_d), cycle time (t_0), daily time fund (t_f), number of carriages in the set (n), coefficient of irregularity (k_n) and raw ore weight in the carriage (Q).

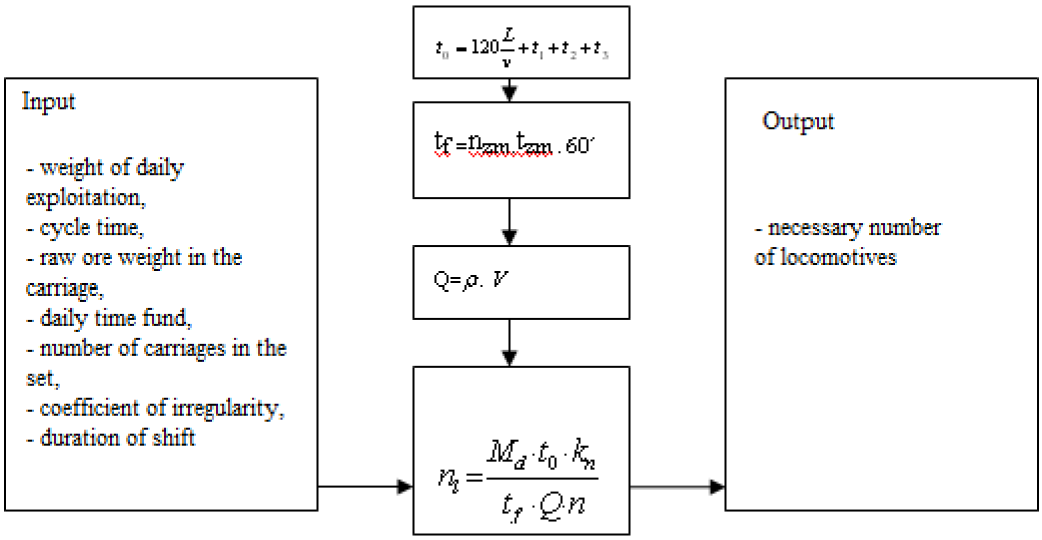

***Figure 5** Hierarchical block „Necessary number of locomotives“*

*3. Hierarchical block **„Necessary number of carriages“*** (Fig. 6) starts from data about weight of daily exploitation (M_d), raw ore weight in the carriage (Q), coefficient of carriages in inactive status (k_1), coefficient of carriages under repair (k_2) and circulating coefficient of carriages (k_0).

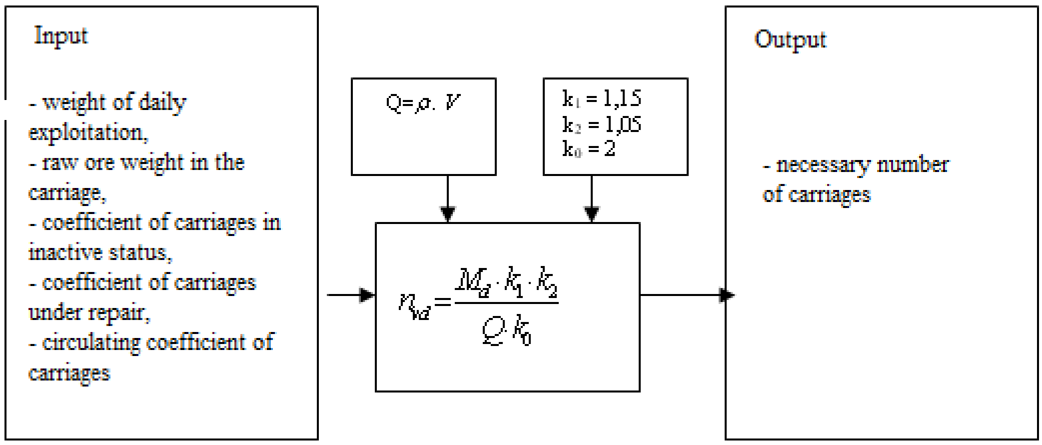

***Figure 6** Hierarchical block „Necessary number of carriages“*

*4.Hierarchical block **„Utilization of locomotives“***. Hierarchical block (Fig. 7) presents the ratio of required capacity of the locomotive per shift and possible capacity of the locomotive. If we have good organization of operation, it will be 70%.

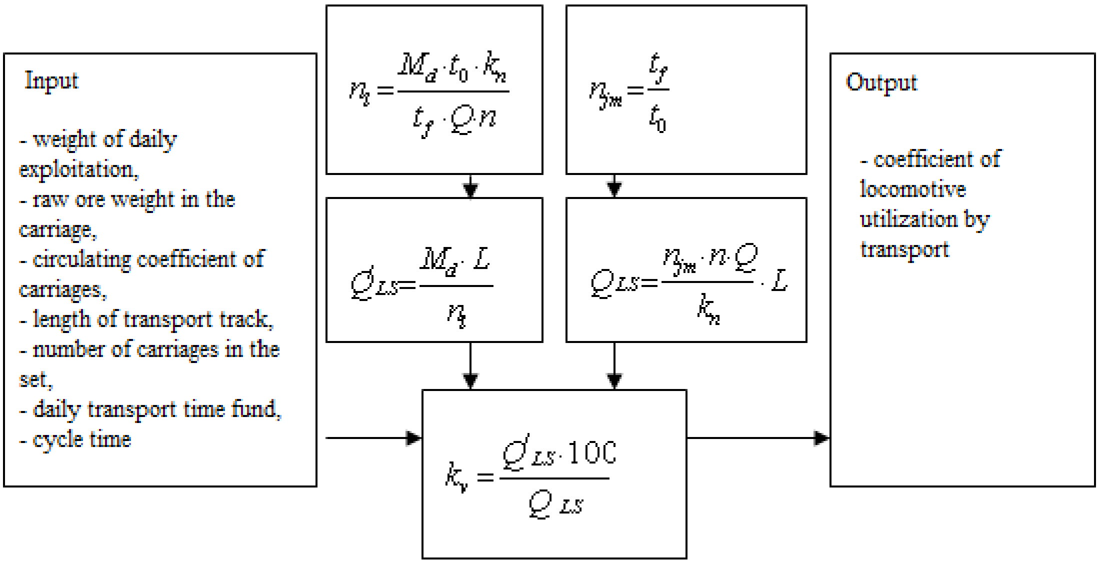

Figure 7 *Hierarchical block „Využitie lokomotív"*

Verification of simulation model in the program Extend is suitable by comparison of its results with mathematical calculation. Correctness of the created computational model verifies results set forth in the Table 1.

Tab. 1 *Comparison of input data of mathematical calculation and computational model*

Data	**Input data**	
	Mathematical calculation	**Computational model**
Cycle time [min]	*15,6*	*15,6*
Necessary number of locomotives [pieces]	*1,37*	*1,37*
Calculation of carriages [pieces]	*19,26*	*19,26*
Necessary number of locomotives [pieces]	*1,26*	*1,26*
Necessary number of carriages [pieces]	*751,3*	*751,3*
Weight of raw ore in the carriage [t]	*2,25*	*2,25*

6.2 Computational model of vertical conveying

The procedure of computational model creation for vertical conveying is the same as the creation of the aforesaid model of rail transport. Fig. 8 presents the computational model of vertical conveying created in the programe Extend.

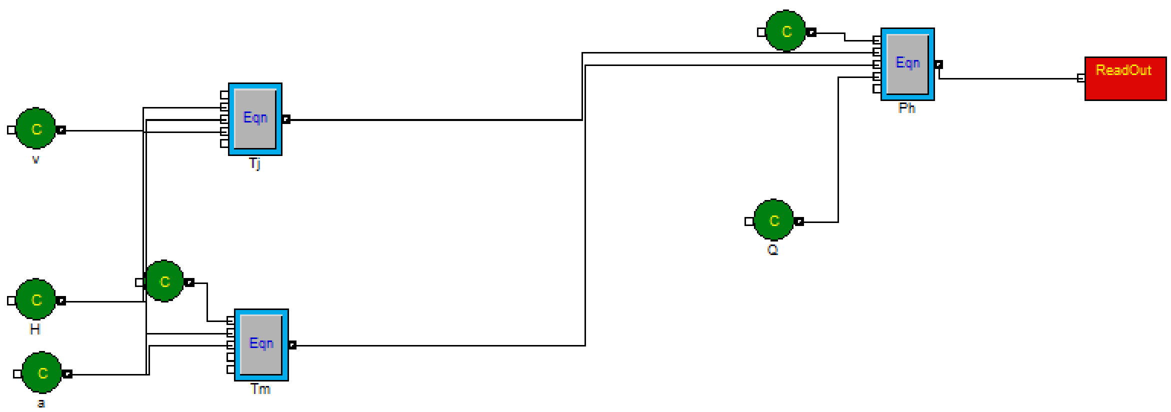

Figure 8 *Computational model of rail transport in the program Extend*

Input data for computational model are:
a) character of transported material (type, specific weight),
b) technical parameters of vertical conveying (track length – depth, standing time, transport time fund, coefficient),
c) technical parameters of vertical conveying (daily exploitation, speed of transport, acceleration).

Accuracy of results of computational model for vertical conveying in the program Extend verifies their comparison to results of mathematical calculation as it presents the Table 2.

Tab. 2 *Comparison 2 of input data of mathematical calculation and computational model*

Data	**Input data**	
	Mathematical calculation	**Computational model**
Total driving time [s]	*45*	*45*
Total operating time [s]	*35,7*	*35,7*
Pulling capacity [t.h^{-1}]	*19,26*	*19,26*

6.3 Simulation model of combined transport

Simulatiom model of combined transport is a combination of rail transport and vertical conveying. Simulation model solves only the field of siderite exploitation from undergroung do the surface according to formalized scheme set forth in [4]. The function of this computer model is a verification of operating parameters of the concrete transport system which is applied in the operation and also a simulation of its work.

Input data to the simulation model of combined transport are:

- character of transported material (type of transported material, specific weight of raw material),
- technical parameters of transport (length of transport track, speed of transport, transport heigth, acceleration, standing time, carriage volume),

- parameters of exploitation (weight of daily exploitation, weight of raw ore in the carriage, standing time, time of loading and unloading, track grade, weight of locomotive, carriage, daily transport time fund etc.).

There are hierarchical blocks from blocks of libraries GENERIC.LIX and PLOTTER.LIX in the simulation model for combination of rail transport and vertical conveying. There is a modelled supply of raw material from exploitation in the hierarchical block „*Ťažba*“, where is possible to select minimum and maximum amount of raw materials in unit ton per second. Raw materials go to the hierarchical block „*Nakládka surovín*“ where are entered and simulated data about raw ore weight in the carriage, number of carriage and time of carriage loading. We define data about transport track length, speed of transport and standing time (standing time in the discharging station, standing time in the track) in the hierarchical block „*Koľajová doprava*“. We enter data about pit depth (h), speed of transport (v) in the vertical conveying and its acceleration (a), number of turnovers and operating time (T_m) in the hierarchical block „*Zvislá doprava*“.

Entering of parameters in the model is realized by the help of „*Notebook*“, which was used for cloning of dialog boxes by the help of which we define parameters of rail transport and vertical conveying. It makes possible their entering and also it eliminates the possibility of parameters skip. Input data are easily changeable by the help of parameter change in the notebook (Fig. 5). Program makes possible fast and simple change of parameters and also a connection with other programs as Excel, Autocad.

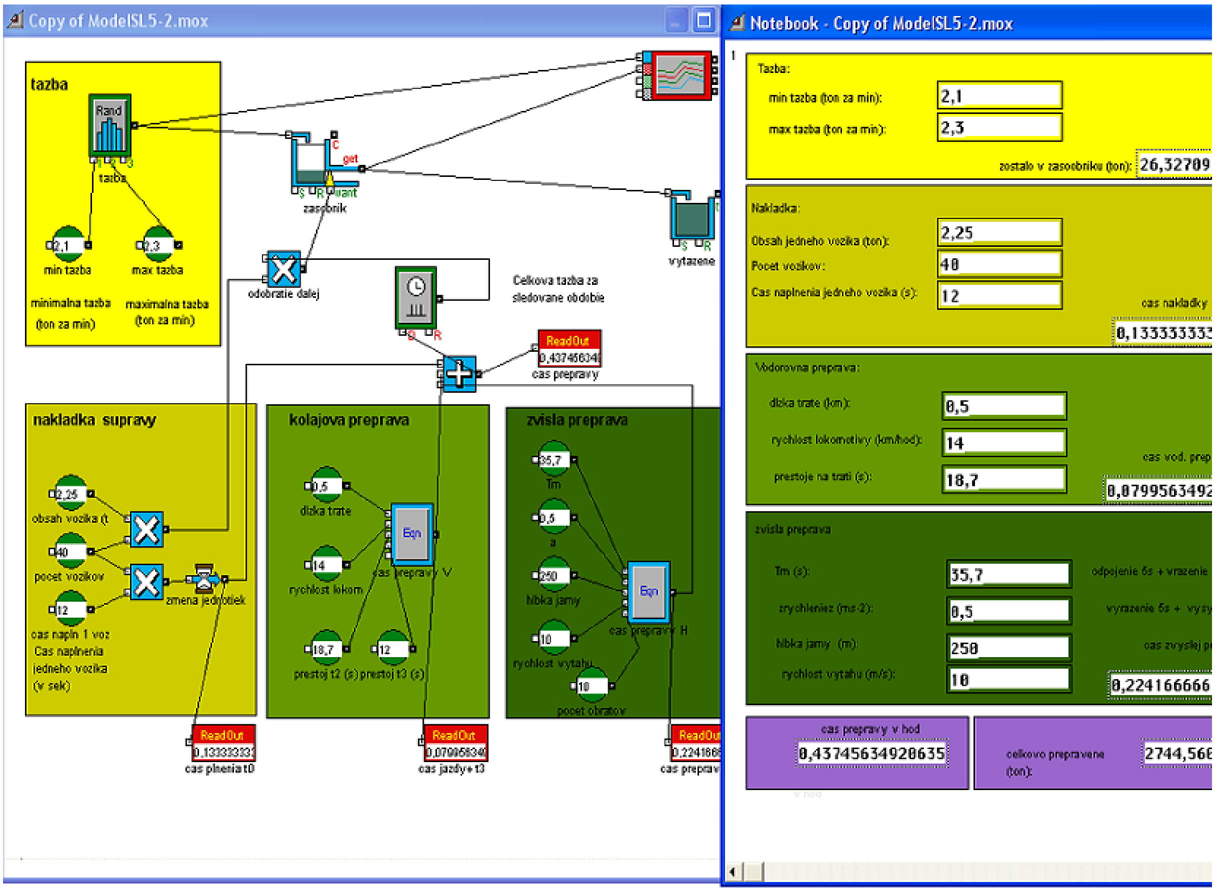

Figure 9 *Notebook from the program Extend for combined transport*

7 CONCLUSIONS

Simulation model solves the field of siderite exploitation from the underground to the surface, whilst the created model makes possible to simulate operating parameters of integrated system of transport (IDS created by rail transport and vertical conveying) which is possible to apply in the concrete operation of Siderite Ltd., Nižná Slaná. The output of the simulation model is an information about amount of transported material, turn around time, raw material balance in the tank. The goal and output of the simulation of siderite transport process is increase of operating capacity, reduction of transportation time and reduction of transportation costs in comparison with the transport composed of only one transport system.

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Review: