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SIMULATION OF EXTRACTION RATE AND SCHEDULING BASED ON GEOLOGICAL AND QUALITY MODELS AS A METHOD OF MINE PLANNING IN MODERN MINING

1. Introduction

Proper production planning is a crucial factor of good financial achievements. It requires detailed geological information and allocation of all available resources i.e. human resources, machinery, energy, financial assets, etc. In times, even though not very distant, that could be called history, planning was carried out with the use of very simple means — the proverbial pencil and a sheet of paper.

General progress in Information Technology combined with Mining Engineers' efforts resulted in various IT solutions, yet supporting only the planning process. In the recent years many professional tools appeared, enabling creating a complete Mine Plan including digital models of deposits, existing and planned excavations with all equipment and utilities (e.g. energy, backfill, etc.). Several relevant technical parameters are assigned to each of these elements, of which the one most important for the usefulness of the applications is time.

Not surprisingly, in modern mining the use of these applications, as a complete planning solution, tends to grow worldwide. They are commonly used in Africa, North America and Australia and more and more frequently in Europe. A similar solution has been introduced in Poland as well. Cooperation between PRGW (Drilling and Geological Works Enterprise) and KWB Turów (Turów Brown Coal Mine) led to the successful implementation of an IT system operating the whole technological mining process. At present, unfortunately, this is the only implementation of this type in Poland. However, judging by the wide interest in the system, an increasing number of implementations can be expected.

Our experience is based on the use of computer programs Mine2-4D and CADSMine developed and licensed by a South African Company GMSI — a member of GijimaAST. CADSMine program works within BENTLEY Microstation environment and exploits its

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capabilities, while Mine2-4D uses its own graphic environment. Mine2-4D can also cooperate fully with BENTLEY Microstation environment.

These applications constitute a part of MRM (Mineral Resource Management) IT solution. Mineral Resource Management (MRM) is a multi-module software suite designed for the mining industry and providing complete solution for mineral resources management. The system focuses on the processes of defining, depletion and reconciliation of mineral resources and reserves. This approach enables planning, optimisation and control of mining activities. The MRM solution is designed to allow integration with other business solutions, e.g. ERP. Effectiveness and practicality of MRM solution has been confirmed in numerous mines and mining enterprises all over the World (Tab. 1).

TABLE 1
Elements of GMSI MRM

Integrated MRM	Geological Modelling
	GeoMap4 (geological mapping)
	Ore reserves
	Mine Design & Scheduling
	Evaluation
	Red Liner (daily correction of the Plan)
	DayCall/MOS (daily planning and control)
	Sampling
	Pegs (complete surveying solution)
	Production Actuals
	Dynamic Reporting

2. Geological and quality models

The starting point to perform a representative extraction rate and development simulation is adequate exploration and documentation of the geological deposit. In the light of this assumption it is very important to use all the information available from all the departments of a Mining Enterprise (geological, surveying and mining departments in particular). Taking into account that the knowledge of the deposit changes and, as practice shows, every day brings with it new information (e.g. new data from exploration drillholes, geological mapping of excavations, laboratory tests results, survey data) that we would like to include in the Plan, the only possible solution is to create a digital model of the geological deposit and its quality models. The Model is created from data saved in a computer Data Base, thus any new information or change in the Data Base can be instantly used in Model update. Collecting and storing all information in one Data Base provides new possibilities in the areas of data verification and analysis, enables various statistical and qualitative analysis with the use of sophisticated calculation algorithms. It is possible to monitor changes of content of the useful elements, content of contaminants, deposit or mineralization zone thickness. A model of the footwall can be also created for its easy identification. There were attempts recently to model in the same way the geotechnical parameters e.g. compressive strength *Rc*. It can be particularly useful in underground mining, where this type of information is derived only from spatially dispersed drillholes.

3. Simulation of exploitation rate

Creation of geological a qualitative models of the deposit provides the possibility to simulate the rate of extraction. The first step towards this goal is a design of access galleries within the geological deposit (in case there was no previous exploitation of the deposit) or the direction of the exploitation. In case of underground mines the design of access galleries has to consider several aspects such as: sufficient distance from gob areas, fault zones or underground water reservoirs, while in the case of open pit mining the focus should be on exploitation sequence. It is also important to properly assign to the excavations their vertical coordinates, as the design is created in three dimensions. The use of IT tools greatly simplifies access gallery design including all the listed above aspects. The design visualization options enable fast evaluation of the designed excavation's position in relation to other elements of the mining environment, and fast changes of their direction, location etc if required. The design of mining excavations has to follow construction requirements and limitations related to their purpose, e.g. maximum inclination angle of a transport gallery. The design modules built into the software automatically detect and report any discrepancies, hence it is possible to carry out all the necessary corrections still at the design stage. Assigning the z-coordinate to the excavations also becomes a simple task. The built-in modules enable projection of the excavations onto the ore(coal)-bed floor model, therefore the excavations have always the right z-coordinate assigned automatically, i.e. they follow the floor of the deposit. IT tools allow assigning proper support to each excavation, in this way providing also an instant access to this information. The engineering department responsible for support design can use this feature. The software provides also an option to create Support Catalogue used later to search and select between support types being applied in a given mine. Selection and assignment of support types to the excavations completes the preparatory stage of the design and enables to proceed to the stage of simulation of extraction rate. The simulation allows verifying all the assumptions as to the position of the access galleries, commencement dates, sequence of the exploitation as well as volume of the mined mineral and its quality parameters without the need to execute any of these works. This procedure, if the results are not satisfactory, enables applying such modifications and corrections to the design as are necessary to achieve the optimum result. Simulation starts from entering the assumed commencement dates of development (in case of access galleries) and extraction (production excavations e.g. long-walls). There is an option available allowing to link the date of commencing a particular excavation to the date of completion of another. This option simplifies planning of exploitation in the cases of continuously advancing excavations such as tunnels or long-wall faces. At every stage of the simulation there is a possibility to introduce technological breaks, if planned (e.g. planned machinery and equipment maintenance). The next step in the simulation is defining the planned rate of advance for each excavation. The rates can be expressed as a number of linear meters per day (or any time unit) or as a volume of output per day (or other time unit). At this stage the types of utilized equipment have to be also assigned to each working place to enable scheduling of machine work at a later stage. Once all the necessary abovementioned tasks are completed the simulation of extraction can start. Depending on the results of the simulation the obtained Mine Plan can be found satisfactory or, in case it does not meet the specified exploitation parameters, can be modified. For that purpose automated tools were developed allowing carrying out analyses of different exploitation scenarios.

Geological model

Selected examples of project stages for geological model are presented on Figures 1–6.

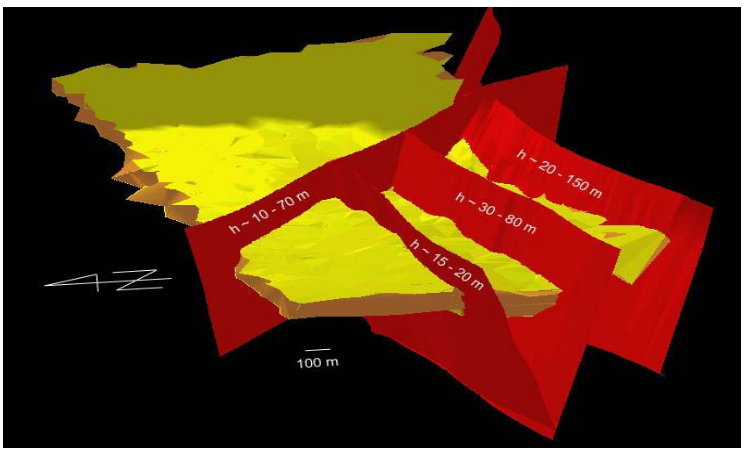


Fig. 1. Model of a coal bed floor surface with indicated fault planes

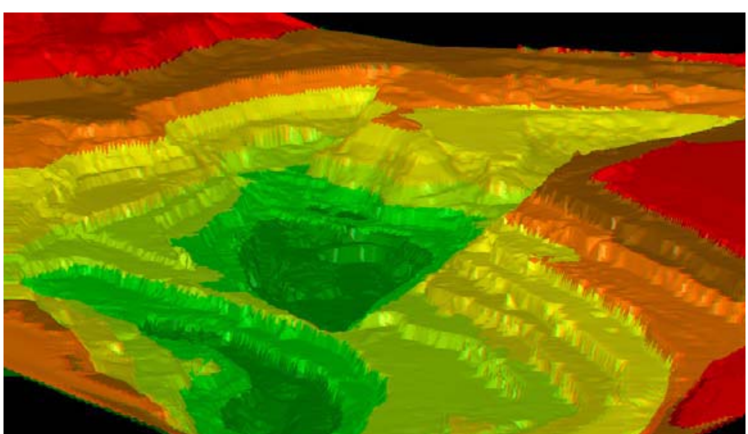


Fig. 2. Model of Turów Brown Coal Mine pit with the exploitation benches indicated

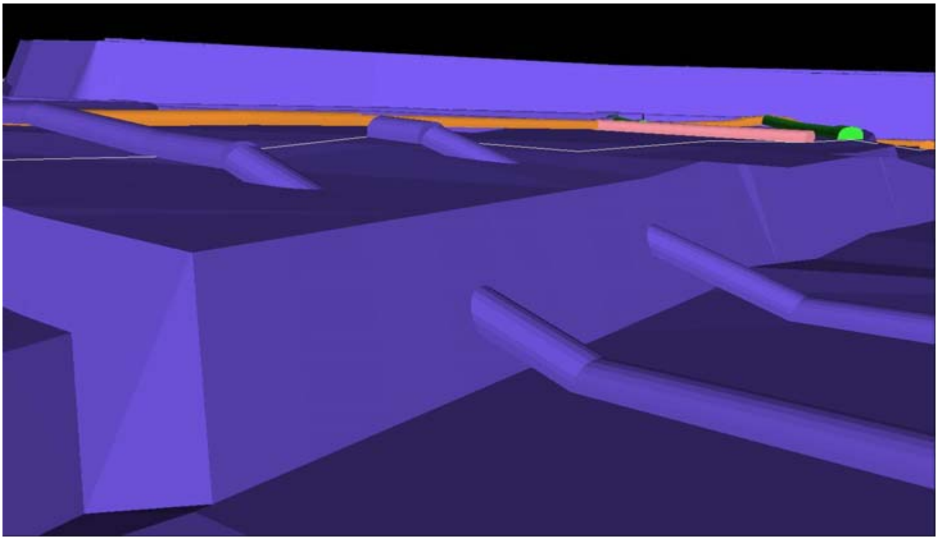


Fig. 3. Visualization of an underground gallery crossing a fault

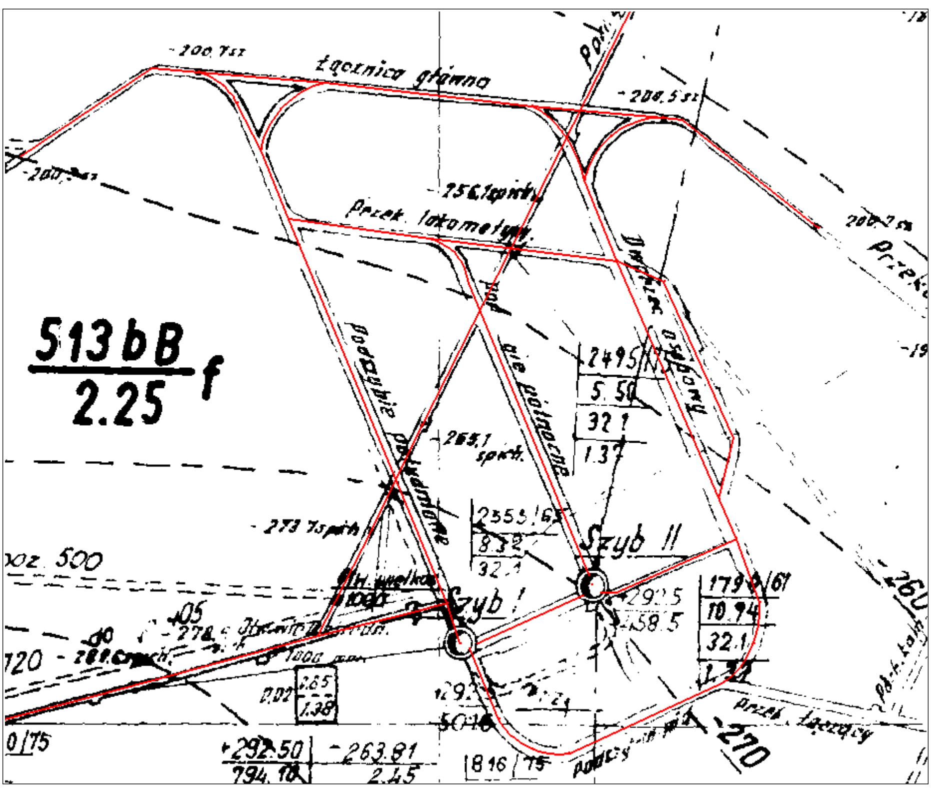


Fig. 4. Digitisation of scanned mine charts

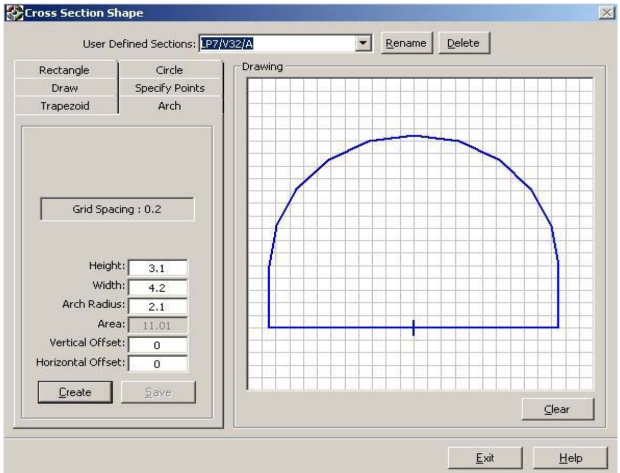


Fig. 5. Interface of a gallery support design module

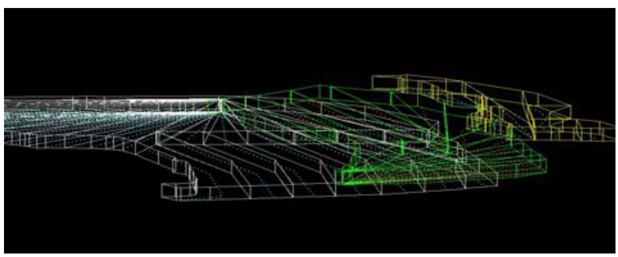


Fig. 6. View of a planned exploitation level

Scheduling

Selected examples of project stages for scheduling are presented on Figures 7–9.

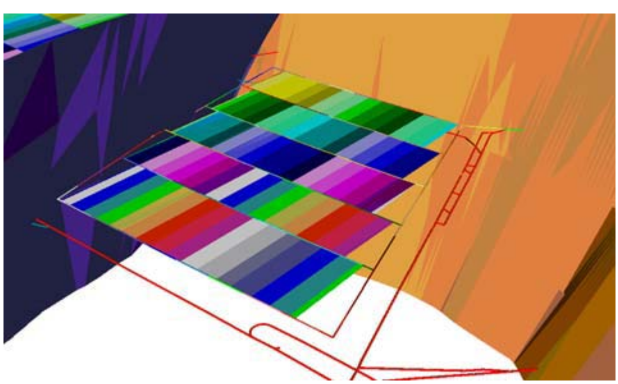


Fig. 7. Monthly progress of the planned exploitation expressed by different colours. Simulation is possible with animated display of subsequent stages of work. Fault surfaces are seen in the background

Fig. 8. Monthly progress of one exploitation bench of Turów Brown Coal Mine

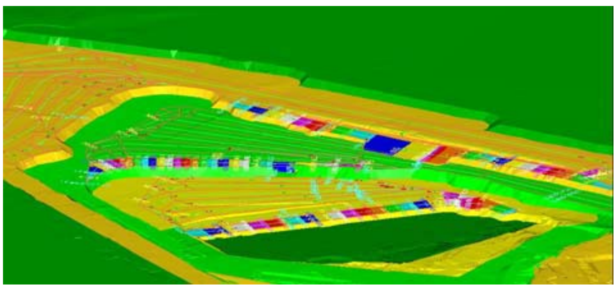
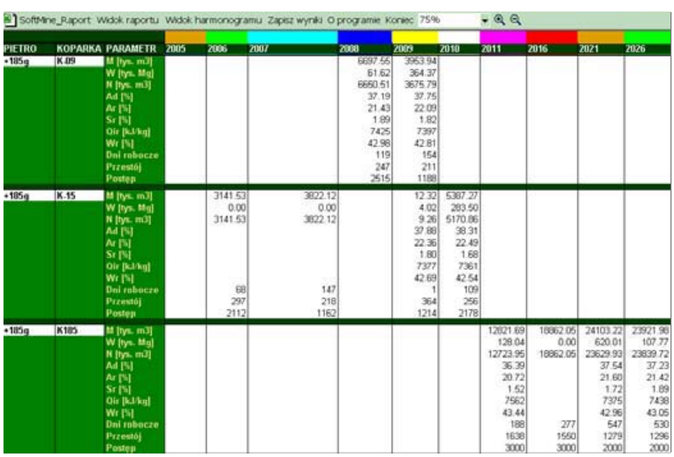


Fig. 9. View of an exploitation bench of Turów Brown Coal Mine
with the monthly progress colour-coded

Schedule of qualitative and quantitative forecasts

Selected examples of project stages for schedule of qualitative and quantitative forecasts are presented on Figures 10 and 11.



SoftMine_Raport Widok raportu Widok harmonogramu Zapisz wyniki O programie Koniec 75%

PIETRO	KOPARKA	PARAMETR	2005	2006	2007	2008	2009	2010	2011	2016	2021	2026
+185g	K.09	M [tys. m3]				6697.55	3953.94					
		W [tys. Mg]				61.62	364.37					
		N [tys. m3]				6660.51	3675.79					
		Ad [%]				37.19	37.75					
		Ar [%]				21.43	22.09					
		Sr [%]				1.89	1.82					
		Qir [kJ/kg]				7425	7397					
		Wr [%]				42.98	42.81					
		Dni robocze				119	154					
		Przestój				247	211					
		Postęp				2515	1188					
+185g	K-15	M [tys. m3]		3141.53	3822.12		12.32	5387.27				
		W [tys. Mg]		0.00	0.00		4.02	283.50				
		N [tys. m3]		3141.53	3822.12		9.26	5170.86				
		Ad [%]					37.88	38.31				
		Ar [%]					22.36	22.49				
		Sr [%]					1.80	1.68				
		Qir [kJ/kg]					7377	7361				
		Wr [%]					42.69	42.54				
		Dni robocze		68	147		1	109				
		Przestój		297	218		364	256				
		Postęp		2112	1162		1214	2178				
+185g	K185	M [tys. m3]							12821.69	18862.05	24103.22	23921.98
		W [tys. Mg]							128.04	0.00	620.01	107.77
		N [tys. m3]							12723.95	18862.05	23629.93	23839.72
		Ad [%]							36.39		37.54	37.23
		Ar [%]							20.72		21.60	21.42
		Sr [%]							1.52		1.72	1.89
		Qir [kJ/kg]							7562		7375	7438
		Wr [%]							43.44		42.96	43.05
		Dni robocze							188	277	547	530
		Przestój							1638	1550	1279	1296
		Postęp							3000	3000	2000	2000

Fig. 10. Tabularized quality parameters obtained with the use of SoftMine Report software working with CADSMine. Both applications are implemented in Turów Brown Coal Mine

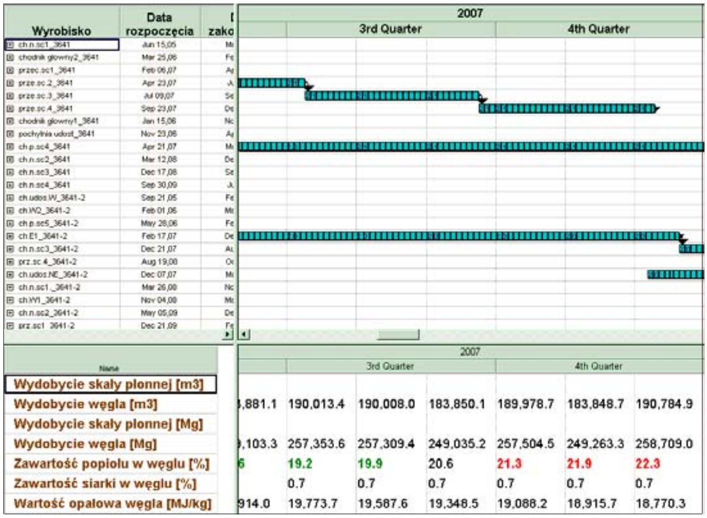


Fig. 11. Schedule and Gantt graphs of access galleries and a longwall
obtained with Earthworks Production Scheduler software — integral part of Mine2-4D

4. Conclusions

Application of IT tools in the process of Mine Planning brings measurable advantages as can be studied on the case of Turów Brown Coal Mine. Before the implementation of the system the Mine planned several major projects related to exploitation and stockpiling. Among others, erecting a main pumping station and purchasing a new dumper were planned. Prior to these investments the Management decided to implement the IT system to support the Mine planning process. As a result of the simulation carried out with the new system it became apparent that the construction of the main pumping station would block exploitation of a large part of the deposit. The simulation proved also that the main pumping station is not necessary. The conventional planning methods did not signal this possibility in any way. It is worth to highlight that just the cost of design of the main pumping station was higher than the cost of the purchased Mine Planning software. Apart from the exploitation simulation, the simulation of stockpiling was carried out including an analysis of stockpiling machinery capacity. The simulation showed that the purchase of a new dumper is not necessary, since the combined capacity of the existing machines is sufficient for the planned level of exploitation and stockpiling. These facts speak for themselves.

Another important feature of the system is the mentioned above short and long term production planning. The obtained Schedule (Fig. 11) shows precisely where, when and, most importantly, what are the parameters of the mined mineral. With this information it is a matter of simple changes in the Schedule to ensure that the product of the Mine complies with the parameters specified by the Customers. This task is achieved by monitoring parameters such as ash content, calorific value, sulphur content, etc. and manoeuvring with the working time and allocation of machinery and people (Gantt charts). Every change is reflected in the graphic design and in the simulation of the exploitation.

The main conclusion of the above overview of the use of mine plan simulation is that mine planning is based on analyses of as many scenarios and variations of the plan as possible. This is obviously understandable in the light of demanding market imposing the most efficient use of geological resources and financial assets. One can therefore expect further development of Information Technology solutions for geology and mining, containing more and more sophisticated options and algorithms.

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