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# Support to IS/IT in Auxiliary Machinery Exploitation Management at the Open-Pit Coal Mine

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## Abstract

With the aim of management improvement, availability and readiness increase and decrease in costs of the exploitation system (operative work and maintenance) of vehicles and operative machines at the open-pit coal mine, the modern business process access with the support of information system and technology was developed and applied (IS/IT). In the operation, the process of exploitation system with the respective software support and Reports development is displayed. IS/IT are designed regarding business processes, monitoring, analysis and management (planning, organizing, management and control) of the exploitation system.

**Keywords:** *open-pit coal mine, auxiliary machinery, operational management.*

## 1. Introduction

Basis for quality management of the exploitation system (operative work and maintenance) make: planned scope of work of the motor vehicles of the rolling stock and operative mining machinery (bulldozers, ditch diggers, skippers, pipe layers...), organization and the maintenance structure, adequate (together with hardware and software) information systems for support to the management of mining exploitation, operation plans for the rolling stock of the auxiliary machinery, data on ongoing maintenance, planned activities and the standards for preventive and corrective maintenance operations, maintenance and supply of the spare parts, available capacities of the operative space and personal, as well as reliability, availability, readiness, maintainability and maintenance costs. Looking at the maintenance system as the support to the operative work, it is clear that all the activities in maintenance must be subordinated to the operative work. Regarding this fact the basis for it make the operative plans for the operation of the vehicles and operative mining machines (in further text defined as in the mining terminology: auxiliary machinery (AP) /1/.

## 2. Business process and IS

According to the analysis of the *Operative system functioning* of the auxiliary machinery in the realization of the auxiliary works and business process model, process model for Auxiliary works was designed regarding IS and QMS, with the defined resources and prominent business goals: Increase in the scope of the performed auxiliary works and operative hours, machines and operators- Resources on which information was kept under the Machine entities, Operators. With the aim of performing business processes based on the principles and quality requirements, the following documents were defined and implemented through the application software /1, 3, 6, 7, 8/:

- Input documents (for example: Sales agreement with buyer, Account for auxiliary works),

- Business process documents (for example: Operation account),
- Reports and reviews for the real time management.

According to the analysis of the *Maintenance system* and general model of the business process, the process model for the Maintenance of the auxiliary machinery of the Company with the defined resources and aims was designed. Activities include: the application for maintenance repair until the delivery of the operative machine with the finished maintenance repair, together with the usage of necessary resources (workshop, qualified staff, spare parts, appliances for testing engines and machines, technical documentation, information system for maintenance system management). It is necessary meet the following objectives: increase of the readiness and availability, together with decrease of maintenance costs.

Auxiliary mining machinery maintenance system includes the support for the process of Technical machines maintenance (in the text below: Machines maintenance) together with the sub processes: preventive (with overhauls) and corrective (upon occurrence of the failure on site) maintenance.

## Operative work

**Functional requirements** for the applicative software of the information system of the auxiliary machinery operative work, i.e. operations of the auxiliary machinery are defined in accordance with the designed activities of the business process and at the same time harmonized with the implemented business process- Auxiliary works that include:

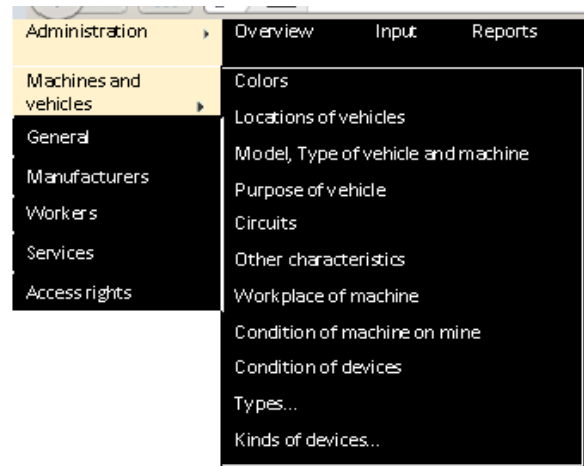
- Auxiliary machinery operative plans.
- Opening of the Orders for the machines and operators.
- Processing of working orders.
- Development of specification for the auxiliary machinery works.

- Auxiliary machinery fuel consumption.
- Review of the fuel consumption reports.

**Realization of the software requirements.** For the auxiliary machinery works, respective software solution was implemented in accordance with the specified functional requirements. Software requirements for the realization of the works of the auxiliary machinery are grouped in the logical packages:

- Maintenance of the technical machine characteristics database
- Maintenance of the data on employees
- Daily deployment of the machines and employees
- Solving of the machine failure on site
- Maintenance of the machine PM
- Support to the fuel management
- Support to the technical liquids and grease management
- Reporting on the operation of the machines and employees (for the operative and top management).

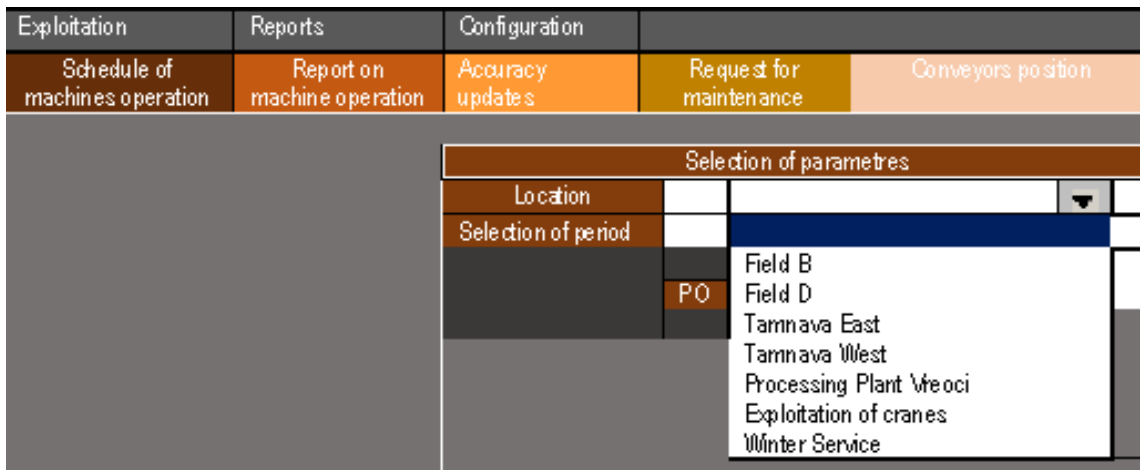
**Examples of screen forms.** For the designed business processes Operative work and Maintenance of the auxiliary machinery (upon logging in) it is accessed to the screen forms: Machine technical characteristics database, figure 1, and Employees database /1,3/.



**Fig. 1 Auxiliary machinery basis: Machines and vehicles**

In accordance with the designed business process, the operations of the auxiliary machinery and requirements given above, as well as with the software development basis of the information system PM, the following specific screen forms are displayed, that illustrate the steps in the realization of the integrity of the operations with the PM machinery usage. The possible scenario of the activities is displayed by the series of screen application software processes:

- Upon the access to the applicative software, the screen with the menu “Exploitation” is opened, then Reports PM, Configuration. By activating “Exploitation“ menus with machines (and operators) schedules are opened, then Report on machine operation, Fluid update, Application for maintenance and Conveyor position.
- Activating of the “Schedule of the machines operation“ is performed through the parameters „Location“-where the machine is going to operate, Fig. 2.



**Fig. 2: schedule of the machines operations: Choice of the machine operation location and machine operator**

- Schedule of the machines operation per choice of the operation location - Figure 3.
- Schedule (daily) of the operation of the available machine type for I, II, III shift (from the drop-down menu: machine operative place, KP-end machine location, employee access code, Mh-Operative hours, G-fuel).
- In the machine operation Schedule, copying of the schedule from the III shift is also performed (KP/EML of

- the machine from the I and II shift, if the machine was not in operation during the II, i.e. the III shift) for the next day of the schedule.
- The documents in hard and/or electronic form with the mark in accordance with the Quality System requirements (for example QZ.EK.2 Schedule of the machines operation, Figure 3).

Fig. 3: Screen form for: (daily) Machine operation schedule depending on the operation location – for the Available Machines from the drop-down menu in shifts: Location of the operation (on site), KP-end position of the machine, Password (of the employee), morning operation schedule

Fig. 4: Machine type entries

- The data in the application “report on machine operation” are entered upon completion of the shift and that from the document „Working order“, with the aim of generating (automatic getting) of the larger Number of reports (for example: on the Number of successfully completed Oh per machine and in total, on fuel consumption: in total and specifically daily, monthly), Fig. 4.
- Monitoring Reload/discharge of fuel/grease/liquid by activating the field “liquids update“, Fig. 5.

Fig. 5: daily data entry on fuel, grease, liquid

Application software supports the requirement of the QMS that refers to the connection business process and business process participant, because authorized access to the applications and data in the information system is provided, in accordance with the roles in the business process performance.

**Maintenance**

Maintenance system of auxiliary machinery includes the sub processes: preventive (with repairs) and corrective (after faults on site) maintenance.

Behavior of the participants in maintaining machine process has been also defined. The result of this attitude is a defined algorithm

of the auxiliary machinery flow and of the participants in machine maintenance on site and in the workshop (Figure 6). The basic flow of the process regarding vehicles in the maintenance includes: fault, repair, and registration for maintenance, machine maintenance, releasing and taking over the machines after the maintenance with the support of electronic documents (forms).

In case of machine fault on site, the machine operator informs the responsible person (dispatcher) about the fault, who informs the workshop by the Registration in electronic form. Depending on the priorities Fig.6, and fault type, the maintenance is carried out on site, or in the workshop according to the algorithm in the figure 6 /3/.

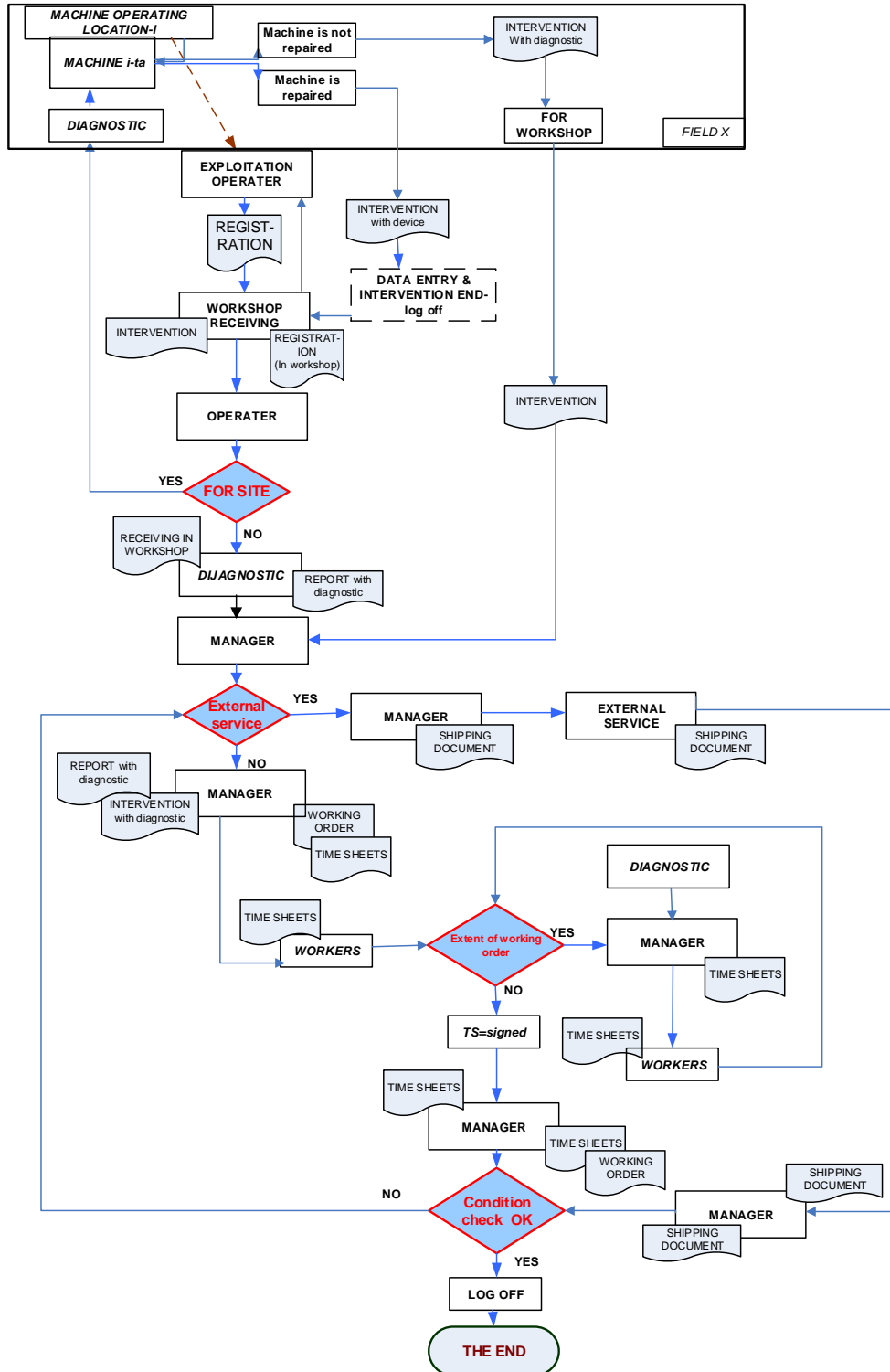


Fig. 6: Algorithm of machine maintenance

Activities include: Admission in the workshop, Diagnostics, making of the work order, making of the Working sheet for the maintenance operators, correction of the Work orders and sheet, control of preformed works. When the machine maintenance is finished, the workshop “releases the machine from the workshop” and the Rolling stock / responsible person of the rolling stock is informed about the end of the maintenance. Then, the rolling stock or the responsible person of the RS Sector ”sees” the released machine on the list, and he can take over the machine from the workshop with the document Taking over.

**Functional requirements of information systems.** Functional requirements for the software are defined by the following activity list of the maintaining business process which should be included:

- Application for maintenance of the RS machine
- Machine registration in the workshop for maintenance
- Diagnostics: diagnostics entry; diagnostics complement
- Work order: making of work order and working sheets; correction of work order, diagnostics complement, closing of work order and working sheets.
- Shipping document (for maintenance in the external services): making the shipping document; closing the shipping document; replacement; take over;

**Reviews and reports:** readiness of rolling stock; rolling stock availability; work order reviews; shipping document reviews; fault history; reports on faults and rolling stock machines' maintenance; maintenance by workers; workers' machine maintenance activities; machine maintenance active time.

**Realization of software requirements.** Software requirements for the realization of the RS machines maintenance are grouped in the following logical packages:

- Registration for maintenance;
- Vehicle maintenance (registration in the workshop, Diagnostics, defining work order and sheets, Shipping document for services outside the RS company, Control, Release from the workshop );
- Taking over the machine after the maintenance;
- Reviews and reports (for example reports on faults and maintenance of machines).

**Examples of screen forms.** According to the designed business Maintenance process of the auxiliary machinery and mentioned functional requirements, as well as previously presented selected basics of development of the software information system “Maintenance“ of PS, in the figures 7 and 8, characteristic screen forms which illustrate the activities in realization of the entire process Maintenance of PS, are displayed.

Application software provides the integration of the previously described concepts and course of maintenance activities and related documents, as well as the monitoring of the workers who preform those activities. Furthermore, the application software provides recording and processing the data for the indicators of the process performances, considering the set business objectives. According to mentioned above follows /3/:

- Data structure of machine database, Fig. 1,
- Machine registration for maintenance (exploitation-registration for maintenance) Figure 6, selection: "Locations"-where the machine shall work; "machine type"; "Type"/drive number; dauoma, shifts of machine operators; "machine position"; "Machine status", Fig. 7; "Repair"; " mechanical assembly ", Fig. 8,
- "Machine fault description" - updating of data of the fault database.

Exploitation	Reports	Configuration		
Schedule of machines operation	Report on machine operation	Accuracy updates	Request for maintenance	Conveyors position
	MB "KOLUBARA"	<b>REGISTRATION FOR MAINTENANCE</b>		Q.Z.EKS.03
	AUXILIARY			Created on
	MECHANISATION			12.01.2012. 08:01
	Location	Type of machine - vehicle	Type/ Drive No.	
	D - Field D	Dozers		
	Date	Shift	Worker	
	12.01.2012 08:00:44	III- Shift III		
	State of counter - MOTO/h	State of counter - KILOMETERS	State of fuel [%]	
	234		37	
	Location of machine - vehicle	Status of of machine - vehicle	Required removal	
	B - 07	operation with defect	<input type="checkbox"/>	
	Regular service	out of order	<input type="checkbox"/>	
	Assembly	operates with defect	<input type="checkbox"/>	
	Description of fault			
		CANCEL	CONFIRM	
Fault priorities				

**Fig.7: Maintenance registration: Machine status selection**

Fig. 8: Maintenance registration: selection of the machine part

**Managing reviews and reports**

According to the quality system, the structure of management team was defined by the business process:

- Top level management is consisted of:
- Director of PS company; CTO; head of operation and maintenance.
- Executive and supervisory management team is consisted of:
- Director of PS company; CTO; head of operation and maintenance; for exploitation; head assistant for maintenance; other operative managers when needed

**Application „Reports“** Application screen form (menu: Reports→Report selection) for the RS management includes navigation menu and data display in real time, Fig. 9. This application enables direct generation of reviews that include performance indicators of business processes and business operations of the company:

Reports on daily engagement of machine operators (menu: Reports→report selection→Report on daily engagement) - Fig. 9.

Selection of the Report

- [Report on daily engagement of operator](#)
- [Machine performance report](#)
- [Report on the consumption of oils and lubricant](#)
- [Review of fuel and lubricant consumption](#)
- [Summary reports on fuel consumption](#)
- [Report on the operation of machines by shifts](#)
- [Daily fuel consumption report](#)
- [Machine location](#)
- [Report on counter status - services](#)
- [Report on refiling / discharge of fuel / lubricant / liquid](#)
- [Review of faults](#)
- [Review of liquid](#)

Fig. 9 Main application form Reports

- Report on machine operation -Fig. 10.
- Report on oil consumption for the systems/ mechanical assemblies, for engine for example.
- Report on fuel consumption and lubricants by machine types and by the machines (bulldozer, pipe layers, fuel consumption by vehicle - graphical display) –Fig. 11,

Fig. 10: Screen form: Report on machine work

- Report on fuel and lubricant consumption by machine type-Fig. 12
- Report on machine work by shifts.
- Machine position (on site).
- Report on mechanization repairs (on site, for example Field D).
- Refilling/defueling.
- Fault review- Fig. 13.

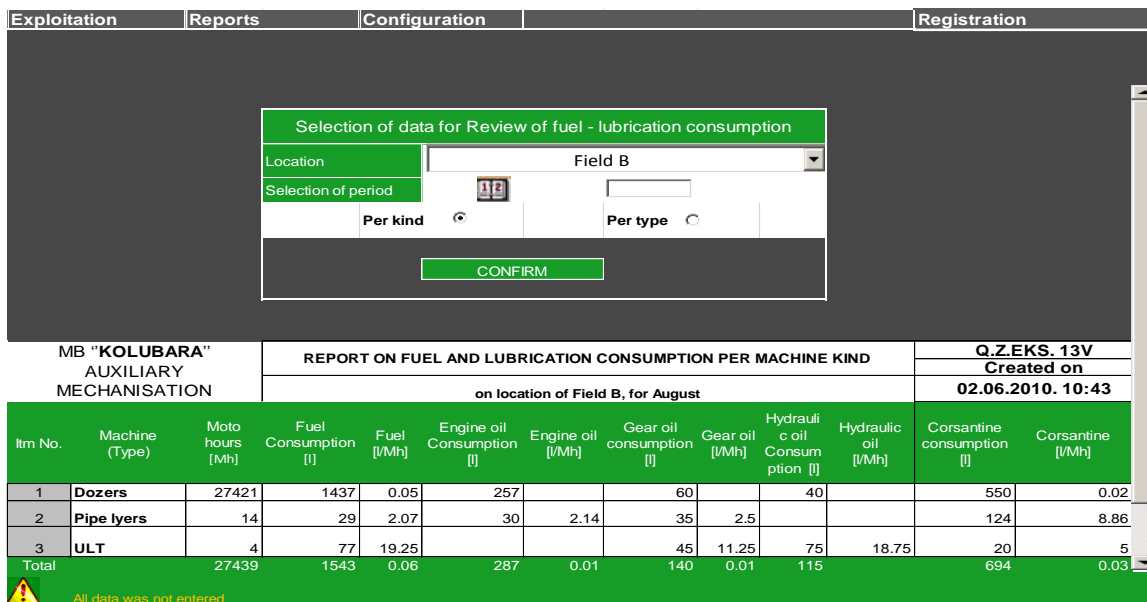
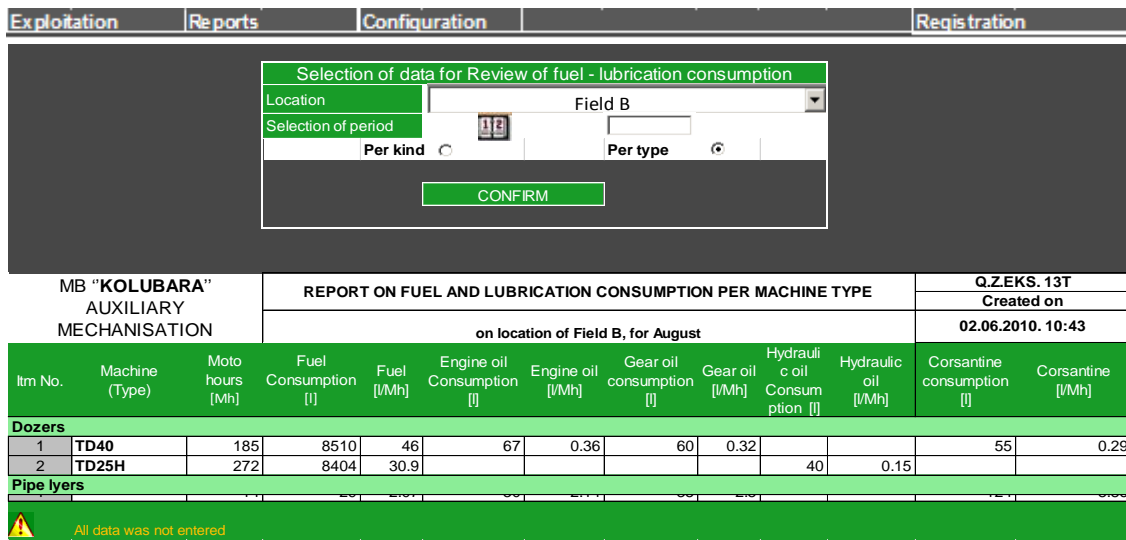


Fig.11: Report on fuel and lubricants by machine types



SI.12 Rep. on fuel and lubricant by machine type

**Report on fault/repair - machine maintenance.** This report is used by the management (Director of PS company; heads and assistants of exploitation and machine maintenance) in order to monitor the

machines during faults and repairs, in order to manage the machine work during faults, Fig. 13, and repairs, Fig. 14., and manage the machine work in ancillary works realization in coal open pit mine.

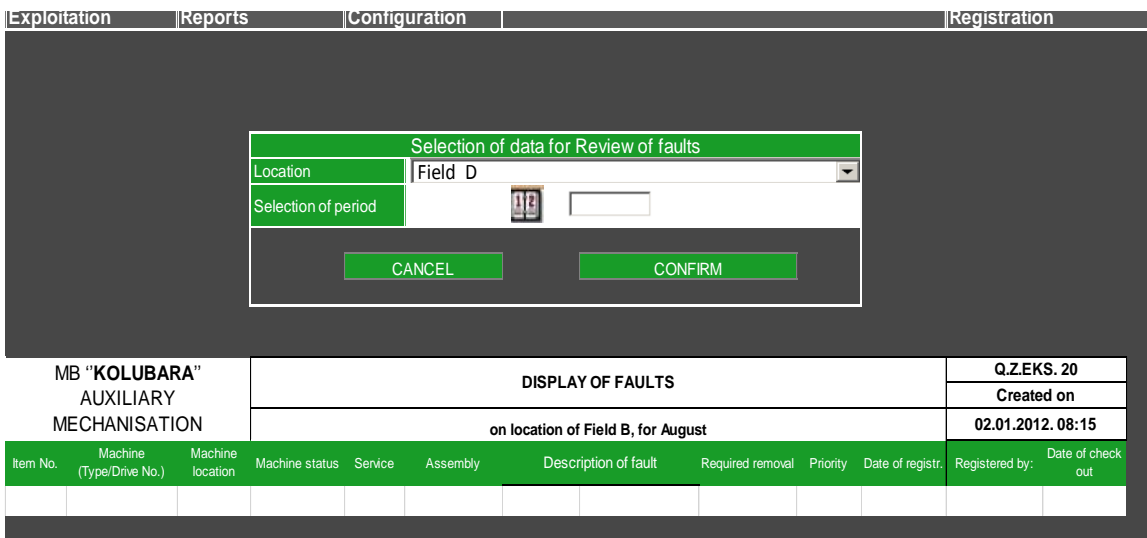


Fig. 13: Screen form: Display of faults

AUXILIARY MECHANISATION		Machines Fault-s/Repair-Maintenance					QZEKS.24	
							Document generated	
Machine kind	Model and Type	Date of registration	Registration No.	Date of receipt	Remark	Assembly	Fault	Date
Dozer	TD25H	15.01.2012 00:00:00	22/12			Engine	Low oil pressure	35,56
		30.12.2011 06:54:52	207/11	30.12.2011 13:23:31	transfer to workshop in order to be tested	Gear	Surplus of oil in engine 3cm	51,27
		30.12.2011 06:54:52	207/11	30.12.2011 13:23:31	transfer to workshop in order to be tested	Gear	gear is losing power during heating of oil	51,27
		18.11.2011 12:29:21	91/11	25.11.2011 14:04:38	transmission. It is required to find a reason	Gear	rise temperature in the gear	93,03
	TD40C	08.11.2011 09:47:49	3/11	25.11.2011 14:04:38	waits a place in the workshop-change of undercarriage, change of damaged pin, side and gears	traveling mechanism	required to change traveling mechanism	103,15
1 2 3 4 5 6 Next Last		Groups per page		1				

Fig. 14: Report on Fault-s/Repair-Maintenance

**Rolling stock availability.** Figure 15 shows the report on „Rolling stock availability“ which contains the indicators of the process performances „Rolling stock“ for every type of the vehicle and for all of them together (e.g. bulldozers 75.71%), model (TD40C 50%) and total (82.39%).

This report enables the operation managers (Head and Head assistants) to perform the auxiliary works to perceive the state of the rolling stock in real time regarding the possibility of planned

tasks realization possibility. This requires the following clarifications:

- for example: if the availability is 50%, then the possible realization of the planned tasks is around 50%, which means that the efforts should be directed to maintenance in order to get the highest possible number of operative machines (which makes the availability higher), or the vehicles should be rented from the third party;
- For example: if the availability is 90%, then the possible realization of the planned tasks is around 90%, however,
- If the average availability is 90.00% and if that availability is used in planning the realization of 100% of the task, then the vehicle maintenance organization is directed to maintaining the availability at the level of at least 90%;
- In case of the task scope increase, the number of vehicles for the realization now has to be higher.

Report on vehicle fuel consumption. Figure 16 shows the report, which refers to daily fuel consumption for the chosen types of (vehicles) for the chosen month and year. For every vehicle, the following could be followed: operator in charge, Operative hours fulfilled, the quantity of fuel consumed (per normative, the realized one and the difference among the values),

AUXILIARY MECHANISATION		Availability		QZEKS.20	
				Document generated on 19.12.2012 12:11	
Kind	Model and Type	Availability			
Dozer	CAT D8R	100,00%			
	TD25H	0,00%			
	TD25M	100,00%			
	TD25M EHTRA	80,00%			
	TD40C	50,00%			
	TD40E	100,00%			
	TD40E EHTRA	100,00%			
Average		75,71%			
Pipe Layer	SB60	100,00%			
	TD25CS-3	100,00%			
	Average	100,00%			
Ditch-digging machine	BG H1000-G	66,67%			
	CAT320-B	50,00%			
	CAT336-DL	100,00%			
	NEW HOLLANDE 265 DEL	100,00%			
Average		79,17%			
Average		82,39%			
Records 1 for 9 from 9		Groups per page		10	

Figure 15 Report on availability



AUXILIARY MECHANISATION			Daily fuel consumption							QZEKS.24	
										Document generated	
Year	Month	Day	Document	Label	Starting Q in l.	Received Q in l	Total l	Filled-in l	Dif. Mac. Cle.	Other	Difference
2011	12	01	429/11	Euro Diesel	2251	6300	8551	255	8296	6652	1644
			429/11	Euro Diesel	1644	0	1644	1644	0	0	0
			430/11	Euro Diesel	1680	5200	6880	4412	2468	2468	0
		Sum			5575	11500	17075	6311	10764	9120	1644
		02	454/11	Euro Diesel	2468	4760	7228	4317	2911	2911	0
			453/11	Euro Diesel	6652	0	6652	2146	4506	4510	-4
		Sum			9120	4760	13880	6463	7417	7421	-4
		03	458/11	Euro Diesel	2911	5130	8041	5205	2836	2836	0
		Sum			2911	5130	8041	5205	2836	2836	0
		04	458/11	Euro Diesel	2836	4965	7801	5361	2440	2440	0
		Sum			2836	4965	7801	5361	2440	2440	0
		05	460/11	Euro Diesel	4510	3050	7560	917	6643	6643	0
			488/11	Euro Diesel	2440	2920	5360	4183	1177	1177	0
		Sum			1187	5760	6947	7821	-874	722	-1596
Records 1 for 1 from 1		Groups per page		20							

Fig. 16: Report on daily fuel consumption

Consumption coefficient and the comparative values of the consumption (according to the normative).

Indicators *Comparison of the consumption* according to the are indicators analyzed by operations management. In cases of significant difference from the standard normativa, management takes measures: standards review for a certain type and brand of the vehicle, as well as verification of the data about the performed scope of works, performed services and fuel load.

Review of fulfilled Operative hours and spent liters for one specific vehicle is shown by the chart in picture 17. The chart enables easy comparison of the production indicator elements trends– Operative hours fulfilled [Oh] and average fuel [l] during the year, by months. Based on the data from the table (e.g. monthly indicators as on Figure 17) and the trend analysis for a specific vehicle, the management makes the decision whether the detailed analysis of the data about vehicle performance and its fuel consumption should be further analyzed in details.

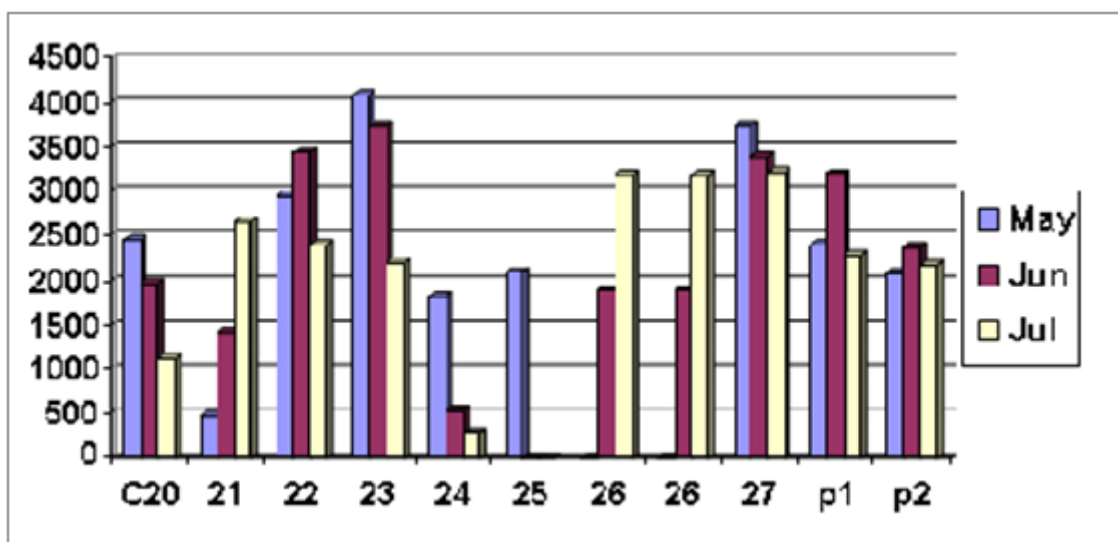


Fig. 17: Report on monthly fuel consumption for pipe layer

### 3. Conclusion

Based on everything shown in this paper, it can be concluded that the set goal was achieved: the operating processes and IS with the suitable application software for auxiliary machinery management were developed for the realization of auxiliary (operative work)

and maintenance of the vehicles and machines at the open-pit coal mine.

This enabled the "easier" planning, organizing, managing and monitoring of the planned tasks realization of the operative work system and maintenance system, in real time. Because of it, the data and information, thanks to IS are generated in real time and in

constant interaction with operative works and maintenance business processes realization, which contributes to raising of its management, as well as the reliability and availability, and decrease in exploitation of auxiliary machinery in total.

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