Support to IS/IT in Auxiliary Machinery Exploitation Mangement 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.

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).

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/.

For the 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

- Scedule 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).
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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

![Fig. 6: Algotithm of machine maintenance](image-url)
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 perform 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; daouma, 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.

![Fig.7: Maintenance registration: Machine status selection](image-url)
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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:

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

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

- Report on fuel and lubricant consumption by machine type-Fig. 12
- Report on machine work by shifts.
- Machine position (on site).

Managing reviews and reports

- Report on mechanization repairs (on site, for example Field D).
- Refilling/defueling.
- Fault review- Fig. 13.

Fig. 9 Main application form Reports
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Fig. 11: Report on fuel and lubricants by machine types

Sl.12 Rep. on fuel and lubricant by 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
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**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),

**TABLE 1**

<table>
<thead>
<tr>
<th>Machine kind</th>
<th>Model and Type</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dozer</td>
<td>TD25H</td>
<td>100.00%</td>
</tr>
<tr>
<td></td>
<td>TD32H</td>
<td>100.00%</td>
</tr>
<tr>
<td></td>
<td>TD32EH</td>
<td>80.00%</td>
</tr>
<tr>
<td></td>
<td>TD40C</td>
<td>50.00%</td>
</tr>
<tr>
<td></td>
<td>TD40C-2L</td>
<td>100.00%</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>75.21%</td>
</tr>
<tr>
<td>Blue layer</td>
<td>D-900</td>
<td>100.00%</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>100.00%</td>
</tr>
<tr>
<td>Backhoe loader</td>
<td>LGT 2000 G</td>
<td>98.00%</td>
</tr>
<tr>
<td>Average</td>
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<td>100.00%</td>
</tr>
<tr>
<td>Document generated on 19.12.2021 12:00</td>
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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.

References

Report for the project:

[1] Ivanović, G., Milanović, D., Mirković, S. and others, The analysis of the existing system of maintenance and information system for vehicle and auxiliary machinery maintenance with the proposed activities for development and implementation of information system for maintenance system management in Mining basin “Kolubara”, Report no. MV 2227/05 Faculty of Mechanical Engineering, 2005.


Chapters in books:


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