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Improvement of Business Operation by Application of ICT in the Open-Pit Coal Mine

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Abstract

Public Enterprise "Thermal Power Plants and Open Pit Mines Kostolac" designed, developed and implemented ICT) namely, GPS/GPRS and IS/IT on the open coal pit mine "Drmno" in Serbia, for the management of construction and mining machines (bulldozers, excavators, cranes, pipe layers, ...) and vehicles (fuel tankers, transport of workers and cargo, ...) of auxiliary machinery. The aim of the application of ICT in the management of auxiliary machinery is successful organization and better use of resources while ensuring the planned work of basic machinery (excavator, stackers) at the excavation of waste rock and coal.

This paper presents the application of ICT in auxiliary machinery on open coal pit mines with the corresponding system and software solutions for the management of machines and vehicles. The results of the application provide the parameters of operation (position, trajectory, operating time, fuel consumption ...), machines and vehicles from operational work, in real time. This ensures the successful management of the operation of machines and vehicles in real time.

Keywords: open coal pit mine, auxiliary machinery, operational management, ICT, GPS/GPRS

1. Introduction

Application of modern approaches to managing operations of auxiliary machinery and vehicles (AM) in Serbia at open coal pit mines is not present, which is not the case with developed countries, where they already apply. The Thermal Power Plants and Open Pit Mines Kostolac (TE-KO) management's perception that the application of modern approaches in managing AM may achieve significant improvements lead to the implementation and application of Information and Communication Technology (ICT), namely Global Positioning System/ General Packet Radio Service (GPS/GPRS) and Information System/Information Technology (IS/IT) in the open coal pit mine "Drmno", Fig. 1, of the TE-KO.

AM on the open pit coal mine "Drmno" plays an important role in the performance of auxiliary works (works on the planning of floor level, works on cleaning, works on shaping bevels, works on moving, extending, shortening or transferring conveyor, works on the development and maintenance of access roads, terraces, ramps, various embankments and kerfs, canals and collectors for pit water drainage, works on the formation of landfill area at the stage of technical re-cultivation, work in the domain of current and investment maintenance of equipment, ...) that are a support to better use of production technology systems, i.e. machines of basic machinery (excavators, stackers, transport systems). In order to manage operational activities of AM, it is important to have real time information about the location of equipment/ vehicles, their status (i.e., whether they are active) and the level of fuel in their tanks. It is estimated that this can be solved by using ICT, that is, GPS/GPRS technologies in the production area on the open pit coal mines of the machinery and vehicles AM TE-KO.[1,2,3,4]

Fig. 1 The open coal pit mine "Drmno"

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In order to apply ICT in the management of AM an analysis of the current state of AM management has been performed. The situation analysis determined that the AM management does not apply modern approaches to business operations, such as end-to-end business process and ICT. Starting from the existing situation, the design has been prepared, as well as development and implementation of business processes with the support of modern IS with the corresponding software solutions and support of GPS/GPRS technologies.

On the open pit coal mine "Drmno", the dispatcher had to know the location of each machine/vehicle in the open coal pit mines and to use oral communication to find the exact position of machinery/vehicles. Nowadays, Fig. 2, by ICT application, that is, GPS/GPRS technologies, the dispatcher is being enabled to show the exact position of machinery/vehicles on the coal pit mine.[2] And not only the positions of vehicles and AM machinery, but the position of machines of basic machinery too. The system also provides information on the distance of the individual machines/vehicle of the machines of Basic Machinery (BM). This allows the dispatcher, if necessary, to determine the "nearest" machine for working in the immediate vicinity of the machine of BM.

Thus, modern ICT, namely GPS/GPRS and IS/IT have been implemented for management of machines and vehicles AM, which have been operating successfully for several years in the open coal pit mine "Drmno". The following is a presentation of the ICT and results or the data and information that are provided by GPS/GPRS system for AM management in real time.

Fig. 2 Map with the machines and vehicles AM, excavators and stackers BM

2. Development and implementation ICT

In accordance with thoroughly defined terms of reference from the standpoint of design, development and implementation of ICT, namely, GPS/GPRS and IS/IT of machines and vehicles AM, the following activities were carried out in the open coal pit mine.[1,2,3]

Monitoring of the movement of machinery/vehicles AM performed via GPS receiver that is an integral part of the SPIDER controller. SPIDER controller (developed and manufactured at the "Mihajlo Pupin" Institute Beograd), via its digital input, receives information that the engine is switched on, and register in the controller counts

seconds of operation. Fuel level meter is read via the analogue input in SPIDER controller. GPS/GPRS device, every 80 seconds, sends the message to the communication server with information about the time the message is sent, the time of operation, the engine run time and the value of the fuel level meter.

Physical architecture of the System. Fig. 3 shows the physical architecture of GPS/GPRS systems AM TE-KO with the main components.[2] The system consists of SPIDER devices mounted on machines and vehicles AM, communication server, application server and database server, GPRS router (gateway), work stations that access application server and the GPRS and VPN networks for the transmission of messages from the AM units to the server.
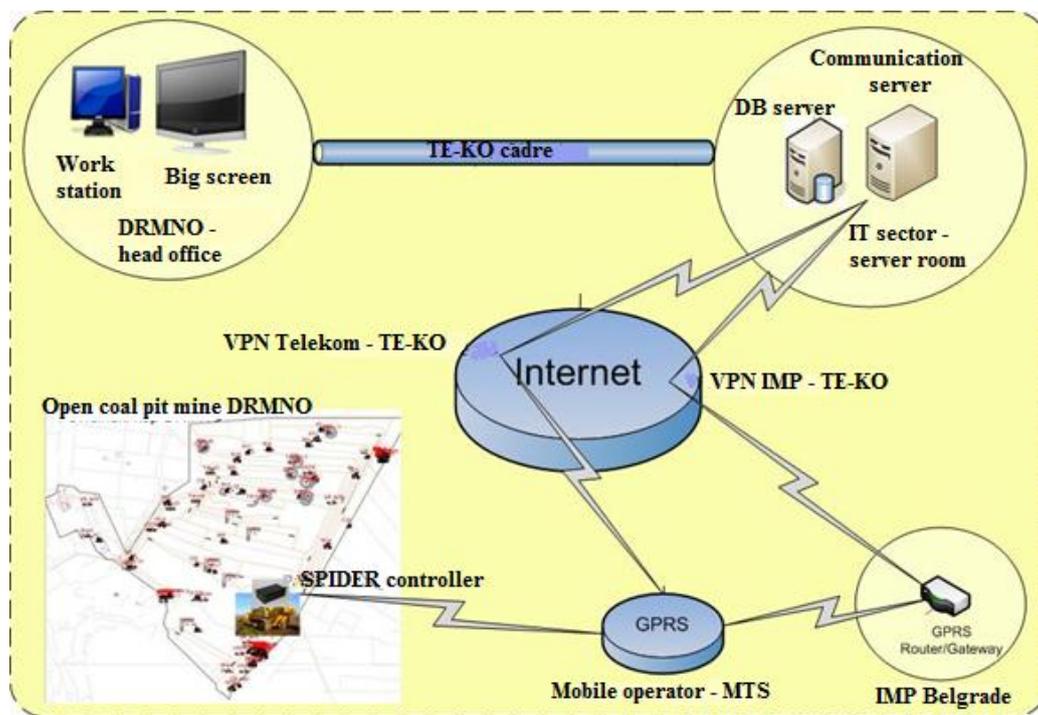
Fig. 3: Scheme of the physical architecture of GPS/GPRS system

The production server (Windows Server 2008 R2 Enterprise), the following Oracle technologies are installed and applied:

– Oracle 11g R2. Oracle system for database management.
– Oracle WebLogic 11g cluster. Oracle WebLogic Server is a scalable application server based on the Java platform, which provides an environment for storing and launching Java EE applications.
– Oracle Application Development Framework Runtime ADF 11g R2.
– Oracle MapViewer 11g and Oracle Map Builder 11g (part of delivery MapViewer) the technology used for the map preparation of the open coal pit mine "Drmno".

Web application for monitoring AM on the coal pit mine "Drmno" is installed on the WebLogic application server. For the reception of GPS/GPRS data in the database, the service is implemented at the application server. The application incorporates Oracle maps. Oracle folder is an umbrella term for a set of technologies that enable high performance interactive Web apps with folders. The synergy of these technologies with ADF framework and other specified Oracle technologies has enabled the realization of modern applications in accordance with the current principles and standards of software development.
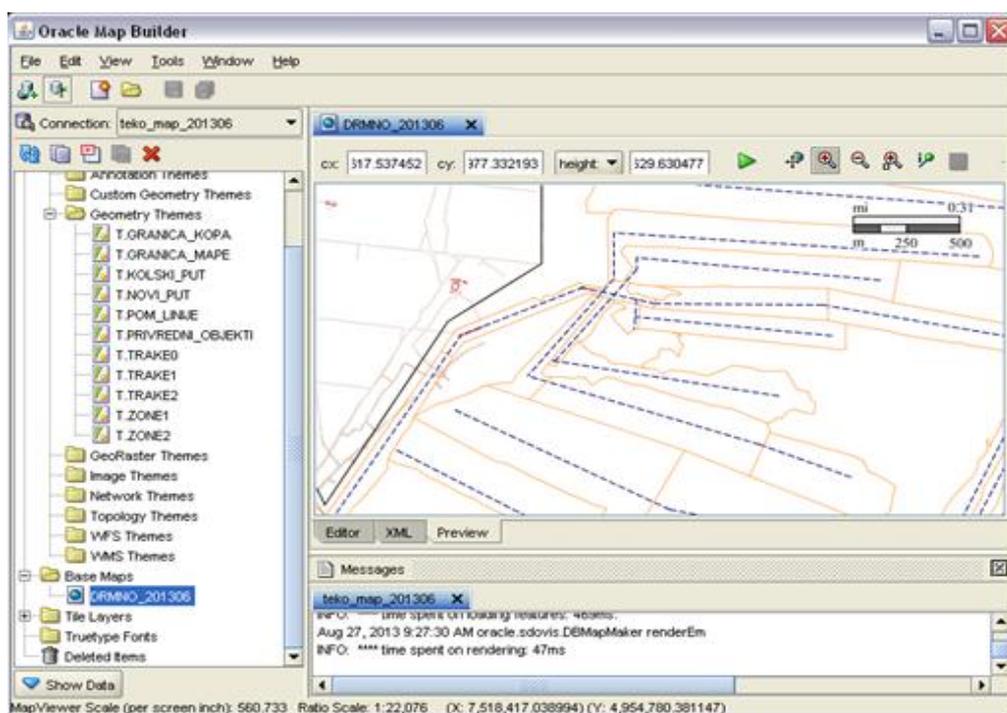
Fig. 4: Oracle Map Builder digs "Drmno"

Site in the GPS/GPRS system of auxiliary machinery. Implementation of maps of the coal pit mine Drmno into GPS/GPRS auxiliary machinery is primarily based on Oracle technologies, Fig. 4.

The system supports storing different versions of the map of coal pit mine. Given the fact that geospatial data used for the map application does not take up much space in the database, the following approach is selected: for each new Drmno coal pit mine map, loading of updated geospatial data (ESRI shape files) in the newly created database scheme of the standardized name. Previously created metadata (styles, themes, map bases) also must be loaded (and potentially updated), as well as the tile layer. It is also possible to perform map redesign. In case you want to add a new geospatial data (new layer/layers), map redesign and recreating of tile layer is necessary.

3. ICT in the poduction area

The application of the applied ICTs, that is, GPS/GPRS and IS/IT for machines and vehicles AM (and BM), provides an improved management on the open coal pit mine "Drmno" in the production area, in real time.

158 GPS/GPRS devices has been installed in 79 machines (bulldozers, pipe layers, combined machines, .), 64 vehicles (wheeled tractors, passenger vehicles, cistern trucks) and 15 machines of basic machinery (excavators, spreaders), as well as integration with the Information System of Auxiliary Machinery for Exploitation (ISAME).[1,2,3]

Pre-set system enables collecting data from machinery and vehicles AM (and of BM position), sending the collected information using messaging over GPRS networks, acquisition, storage and display of information for operational and top management. On the basis of the received messages and their processing, the values of the received messages are analyzed, which allows generation of reports for operational and top management for menagement in real times.

3.1 The daily schedule of machines and operators in the open coal pit mine
Developed and implemented GPS/GPRS technologies for tracking of machines and vehicles AM enable reading of the positions of their operation in real time. This means that by using geo-referenced maps (best known international providers, such as Google), the positions in relation to the parallels and meridians (G4) are read and displayed on the map. These positions are integrated in the ISAME.[1,2,3,4]
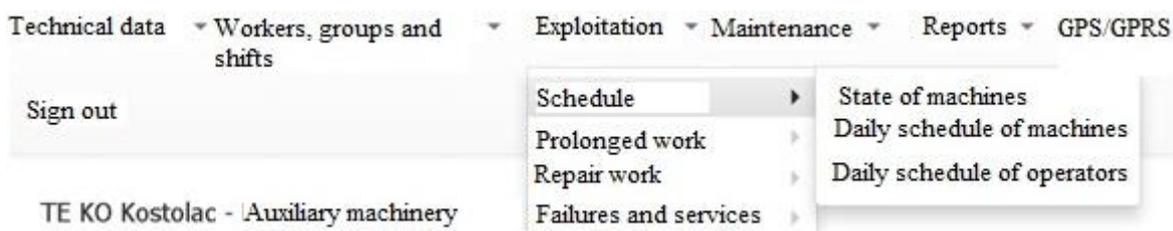

Fig. 5: Daily "Schedule" of machine and machine operators operation

As a consequence of the previous, a business process has been developed "Daily schedule of machines and operators", Fig. 5: "Schedule" for the daily scheduling of machines and machine operators for work in the open coal pit mine "Drmno". Display

forms of "Schedule", Fig. 5, are shown in Fig. 6 for the State of machines, Fig. 7 for Daily schedule of machines and Fig. 8 for Daily schedule of machine operators.

STATUS OF MACHINES on 13/05/2015 in shift I

No.	Internal No. Model / Type	Work mode	Status	GPS position Left - Right	At position
Bulldozer A					
1	A1-TD40C	12	Available	Rad_PMNOV (13.05.2014 10:18:37)	J-II-4D
2	A3-TD40E	8	Available	J-II-4D (13.05.2014 10:18:06)	B.Pump PK
3	A4-TD40E	8	Available	Podina (01.04.2014 06:59:09)	BTD system
4	A2-TD40C	8	Not available	Drobilana (13.05.2014 10:18:49)	Work of_PM machine

Fig. 6: The state of machines,

SCHEDULE OF MACHINES on 13/05/2015 in shift I

No.	Internal No. Model / Type	Position	Work mode	Sector	P1	Works
Bulldozer A						
1	A1-TD40C	J-II-4D	12	Preparation works	J-II-4D	Making of mine slopes 024
2	A3-TD40E	B.Pump PK	8	Drainage	B.Pump PK	Preparation for work 100
3	A4-TD40E	BTD system	8	Preparation works	BTD system	Machine work 103

Fig. 7: Schedule of machines

SCHEDULE OF MACHINE OPERATORS on 13/05/2015 in shift I

No.	Internal No. Model / Type	Position	Work mode	Group	Operator
Bulldozer A					
1	A1-TD40C	J-II-4D	12	A	Redić Nenad (3 Agencija)
2	A3-TD40E	B.Pump PK	8	A	Stanojević Ivica (14665)
3	A4-TD40E	BTD system	8	A	Đorđevic Draško (OML/18)
4	A2-TD40C	Work of_PM machine	8	K	Perić Petar (4 OMZ)

Sl. 8 Schedule of machine operators

3.2 Reviews and reports, documents from ICT

Reviews and reports from the ICT (GPS/GPRS and ISPME) are obtained via generated documents in real time.[1,2,3]

Readiness. Readiness (which includes working time and failure-maintenance time) is one of the key measures of successful operation and maintenance of machines on coal mines. Readiness (which includes working time and time of failure) is one of the key measures of successful operation and maintenance of machines on coal mines. The readiness for machines and vehicles on the coal mines "Drmno" is determined in real time based on data that provides ICT from operational work and maintenance. Based on readiness, it is possible to plan operation of machines for next year, as well as assessment of new machines purchase, or maintenance system improvement, Fig.9.
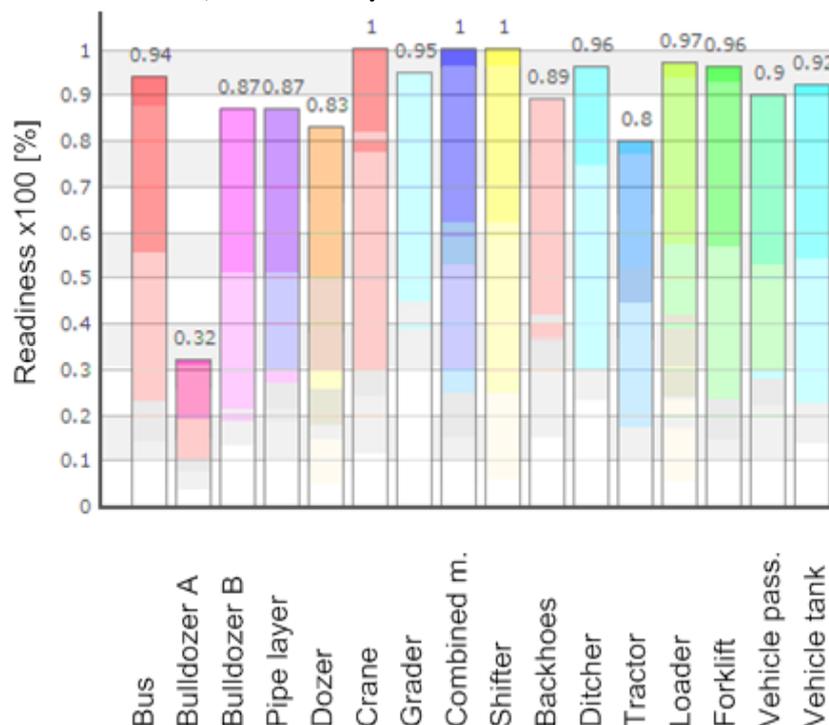
Fig. 9 Readiness of AM machines and vehicles at open-pit mine

GPS/GPRS Reports. Upon accessing applications of the information system of auxiliary machinery for Exploitation-ISAME,[1,2,3] option "GPS/GPRS" is accessed, then the user interface "Reports" thus accessing following documents, Fig. 10, /1, 2/:

– Everyday positions of the machinery/vehicles in the coal pit mine;
– Operation of the machines / vehicles in the coal pit mine;
– Monthly/daily operation of the machine/vehicle in the coal pit mine;
– Monthly/shift operation of the machinery/ vehicles.
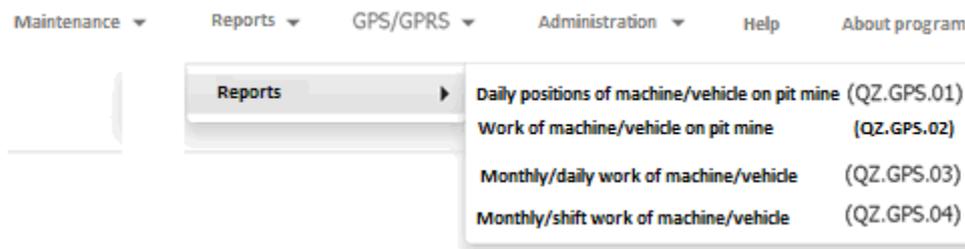
Fig. 10 GPS/GPRS Reports in the Main menu

3.3 Reviews and Reports on the surface coal pit mine map

Machinery and vehicles AM position tracking GPS/GPRS device is equipped with a controller, which allows you to calculate the spatial coordinates of the position of machinery and vehicles, and the position information is sent via the GPRS network to the database server, where the application displays them on the open coal pit mine map "Drmno" as the current position. Pit mine map is being updated in accordance with the movement of excavators and conveyor belts in open pit mine, Fig. 2.[2]

Reviews and Reports from the GPS/GPRS system are obtained directly on the coal pit mine map "Drmno", in real time. Fig. 2 shows the coal pit mine map "Drmno" with all machinery and vehicles AM and machines BM. Waste rock and coal conveyor belts, old and new maintenance workshop, container settlements and an area outside the coal pit mine map "Drmno". Displayed fields can be "expanded" for more precise view of the positions of machinery and vehicles. This is the main map and it is being updated in accordance with the "movement" of the coal pit mine.

It is possible to display on the map one or more types of machinery, vehicles, excavators or stackers, by deactivating the option "All", Fig. 10, and clicking on the selected type of machine / vehicle. Based on the data obtained via GPS / GPRS in the tables on the right side of the screen, from the drop menu, Fig. 8, the following is generated for machinery and vehicles:

– Parameters of AM and BM by accessing with the "mouse arrow" to the selected machine/ vehicle on the map. By clicking on the selected -one machine in real time, following data is displayed: Internal mark (machines / vehicles / excavators, Category 1 bulldozer, Vehicle ID, device ID,
– Time information,
– The time information of the device, the time information of the engine operation and the fuel level in the tank,
– Reviews of "not responding" due to failure of machines, vehicles, excavators, stackers, or GPS / GPRS device are obtained by activating the "Period of not responding",
– Review of trajectory of machinery / vehicles by activating the "Display control" and by entering the date and time from - to the view for the selected machine/vehicle (for examplea bulldozer B10, Dresta TD 40) this trajectory shown in Fig. 11 is obtained
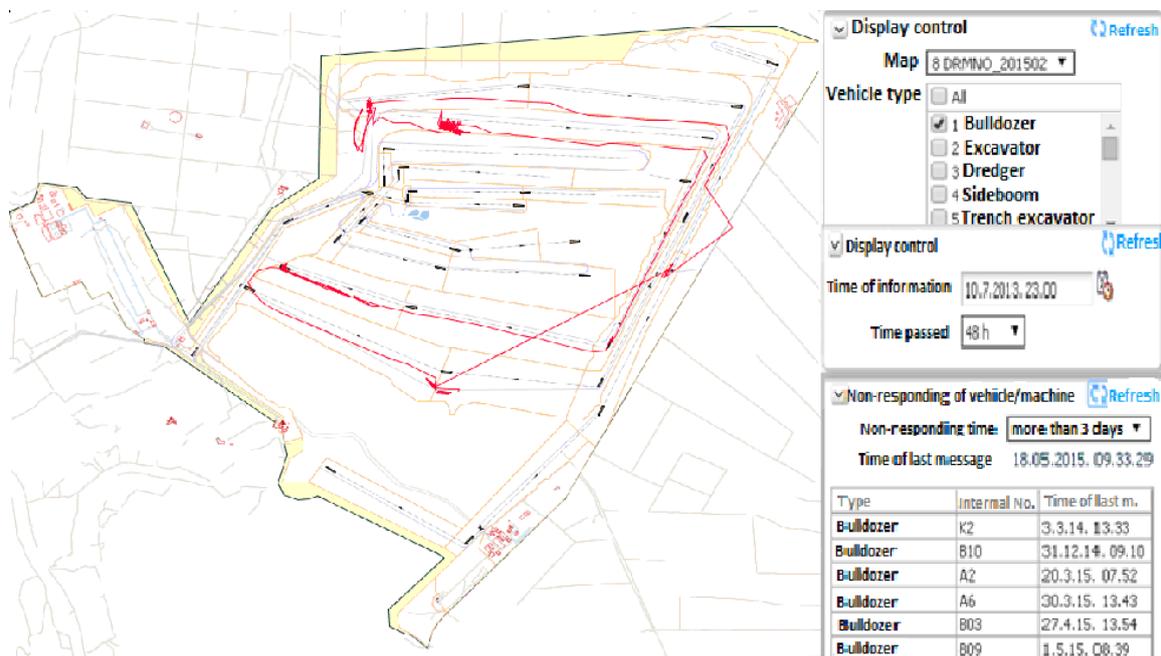
Fig. 11: The trajectory of the bulldozer B10, tables with review of state of machinery/vehicles

3.4 Movement and standstill

Movement and standstill (engine is working) Fig. 12.[2] Based on incoming messages and obtained spatial coordinates of the positions of machinery and vehicles, it is determined whether there has been a movement of machinery / vehicles in the interval between two messages, that is, we get a time when the machine/vehicle was moving or standing between two received messages. On the basis of the positions of the machinery and vehicles AM, the length of the distance travelled and average speed between two messages is being calculated. By adding all the times and lengths in a period between two messages, the information on

time periods of movement and standstill of the machine / vehicle while the engine was running is received, thus calculating the distance travelled, as well as the average speed during one shift of the AM unit.

Engine operation, Fig. 13. Mounted device recognizes the start of the engine through its digital input and starts the internal timer until the engine is running. When sending the message, the numerical value of the counter is also being sent. Based on the differences of the received counter values, engine operation time between two received messages is calculated.
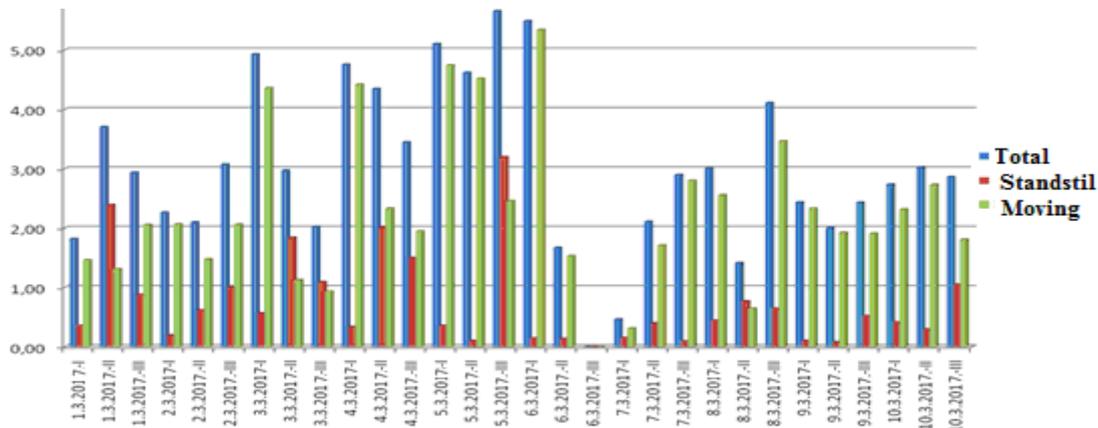
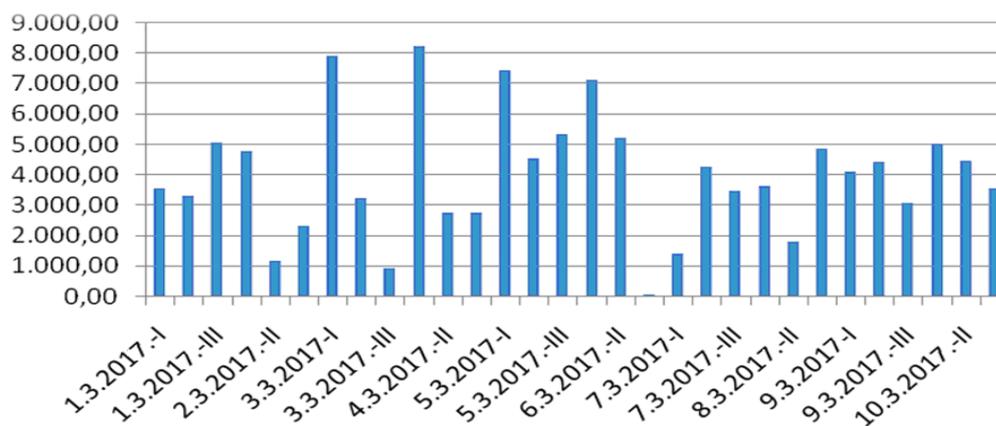**Fig.12: Engine operation while standstill, during movement and total in hours**

Fig. 13 Distance travelled [m] bulldozer TD-25E per shifts

Fuel. At the time of sending messages, GPS/GPRS device takes the value of electrical parameters from the fuel level sensor and sends it to the server and stores it in the database. On the basis of this value the current level of fuel or fuel in the tank is obtained.[2,5]

By comparing the values obtained from the thread messages, conclusion may be made on fuel consumption in operation or topping up the tank, Fig. 14, 15.
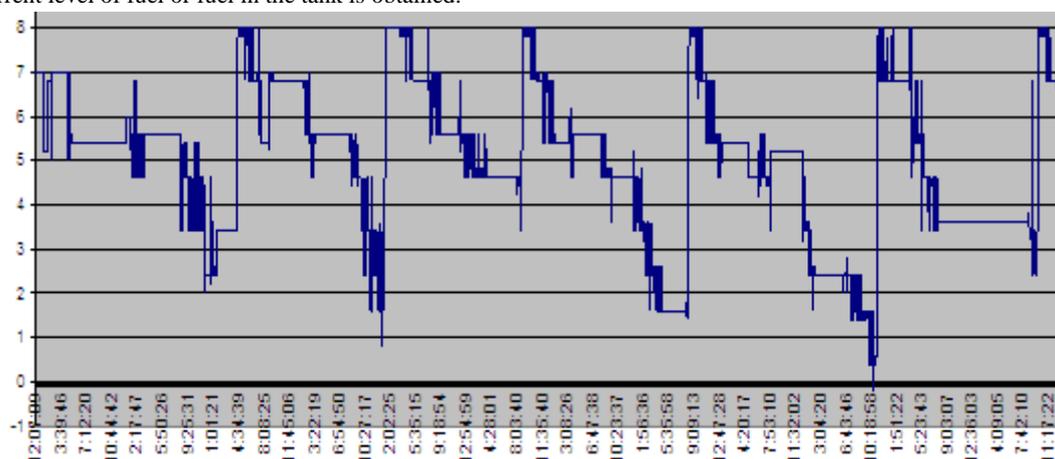

Fig. 14: Emptying and refilling of bulldozers' tank (with non-continuous display of fuel level)
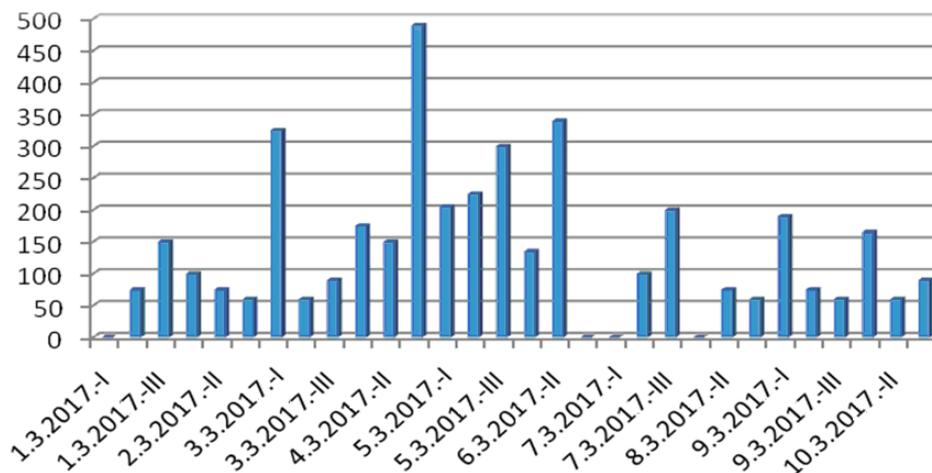
Fig. 14 Emptying and refilling of bulldozers' tank (with non-continuous display of fuel level)
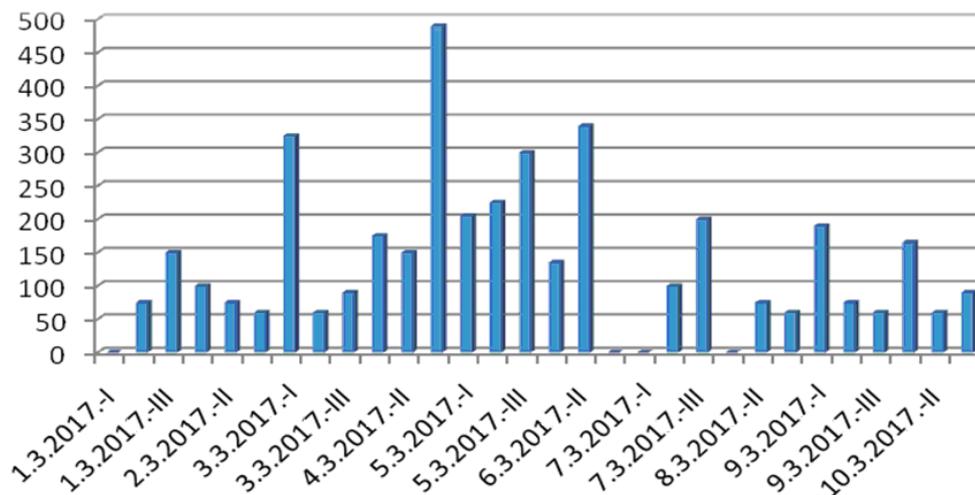

Fig. 15 Fuel consumption [lit] of bulldozer TD-25E per shifts

4. Conclusions

Designed and implemented system of ICT (GPS/GPRS technologies and ISAME) in the open coal pit mine "Drmno" was developed to monitor the operation standpoint (position, fuel level and engine operation) in real time of machines and vehicles of auxiliary machinery and machines of basic machinery.

In addition to monitoring the above, GPS/GPRS and ISPME enables the following too:

- Tracking of the standstill times of machinery / vehicles with the engine running,
- Tracking of the number of travelled km when the engine is running, or during the transportation of the machine,
- Tracking of the state of the fuel level and consumption (initial state - first sign in of the reporting day, filled and consumed during the day),
- The percentage of "standstill" time is determined (machine/vehicle) according to engine "operation time",
- The percentage of "real" fuel consumption compared to "standardized",
- The trajectory of the machine/vehicle in the coal pit mine is being tracked.

These features enable better organization menagement of machines and vehicles and operators and drivers of AM. Optimum conditions for the movement of machines and vehicles in the coal pit mine are also provided due to the display of their positions on the coal pit mine map in real time. The result of the more optimal scheduling of machines is a decline in fuel consumption since the introduction of GPS/GPRS and ISAME until today.

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