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Mine Planning Using RFID

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1. Introduction

A mine is considered to be a plant that produces useful mineral with a given percentage of ore and given quantity, whereas the cost of mining is expected to be minimum. The places of extraction (faces) move in space and time in accordance with the extraction of a rock mass. Mine planning is used to plot variables such as, from which places and how much rock mass to extract, where a miner is working, and what the utilization of any machine is, what the cost of mining is. Geological conditions for mining were determined by nature. They are unpredictable. The environment in a mine is especially harsh: dirty, dusty, and damp. Conditions of mining change randomly all the time.

Many technologies are used in the mining. However, any technology needs a real time data. The data are necessary for a decision-maker to get information about extraction out of each part of a deposit, utilization of each machine, working time of each miner, etc. The information will be used to keep cost to a minimum. For example, a diagram of an underground ore mining is shown on the Fig.1.

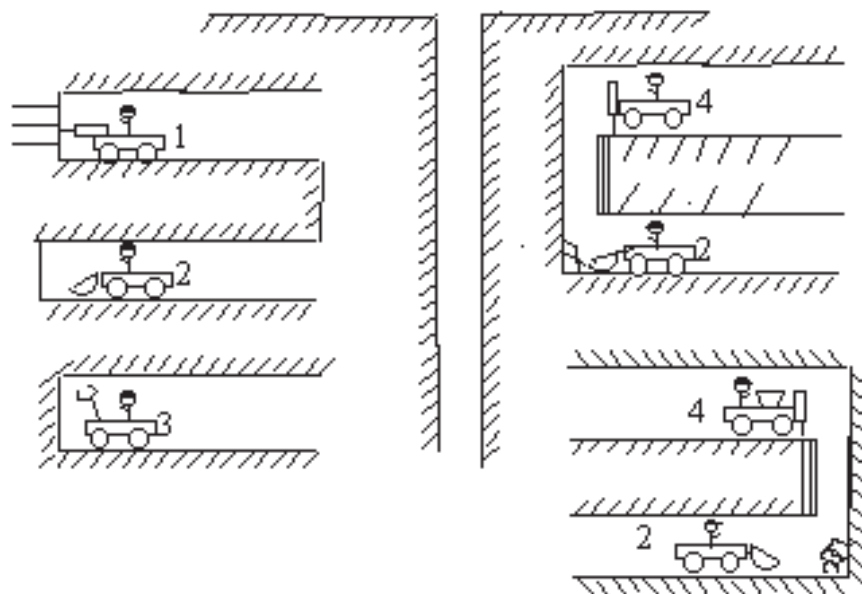


Fig. 1. An example of underground ore mining: 1-drilling machine; 2- loading-haulage-dumping machine; 3- concreting machine; 4- charging machine

The roadways are developed by drilling (1) and charging (4) machines to get access to deposits of ore. After blasting, a concreting machine (3) prepares a roadway. Other drilling and charging machines prepare an extraction chamber. After blasting the rock mass is transported by mobile loading- haulage-dumping machines with a bucket (2) on the distance 30-100 meters to a dumping place.

Many questions for management are not clear enough, such as:

- how much rock mass was delivered from each face;
- what the state of each face is ;
- what condition mine machines are ;
- how long each machine is working;
- who is the driver of each machine;
- what is the utilization of each machine in the mine ;
- where is each miner at present;
- what is the distribution of mine machines in the mine.

To answer such questions, reliable sources of information are necessary.

2. Problems of mine planning

2.1 Surface mining

The shovels, which extract a rock mass, are distributed in a space. Extracted rock mass is transported by trucks to refinery, storage or waste. For example, the layout of an open pit mine is shown in Fig.2.

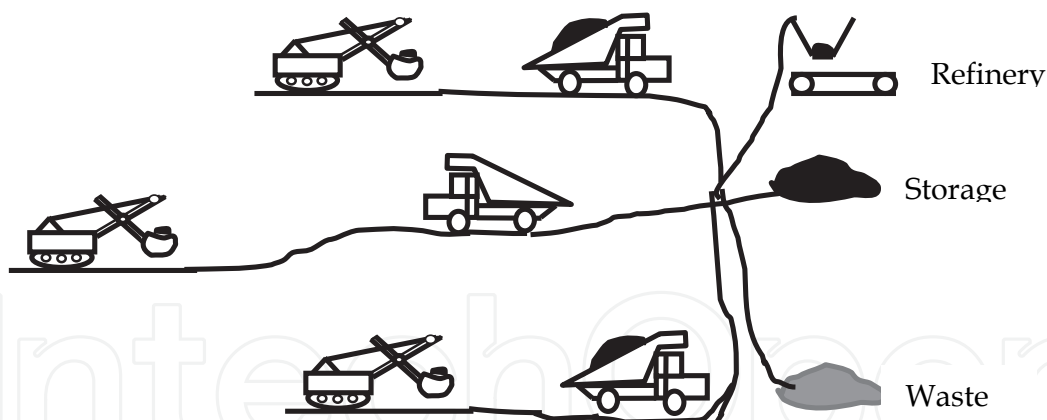


Fig. 2. Mining at an open pit mine

Both shovels and trucks are historically various and have a high cost. That is why the full utilization of shovels and trucks in the system “ N shovels - M trucks” is actual for surface mining. It is actual for management to get current information about trucks and shovels to improve the work of the open pit mine. There were many efforts to determine placement of the trucks and shovels by using a Global Positioning System (GPS), to measure the load of a truck by vibration of body, and to identify a truck by bar-coding. Unfortunately, these ways are difficult and have many limitations for mine planning.

A dispatcher of an open pit mine would like to get the following information:

- ID of i -th ($i=1, M$) truck;
- ID of j -th ($j=1, M$) driver of the truck;
- ID of k -th ($k=1, N$) shovel;
- ID of k -th ($k=1, M$) of the shovel's driver;
- ID of the dumping place;
- current load of i -th truck;
- starting point of i -th truck;
- finish point of i -th truck;
- time of i -th truck's arrival from a known starting point;
- time of i -th truck's departure to a known finishing point;
- quantity of fuel in a i -th truck;
- what a condition of k -th shovel (waiting, loading of rock mass into a back, breakage) is;
- what a condition of i -th truck (movement with rock mass, movement without rock mass, refueling, breakage, loading, dumping, waiting) is;
- what number of trips has the i -th truck taken;
- what number of k -th shovel's buckets were carried by i -th truck.

If the truck situated in loading zone, the shovel loads the truck by several scooping. The number of scooping depends on many factors.

A total time of working cycle T_s for the each machine consists of two parts:

$$T_s = T_w + T_d,$$

where T_w =working time of k -th shovel;

T_d = idle time of k -th shovel.

Using this information, management could get the following indices to improve the activity of the open pit mine:

-the utilization of the i -th truck

$$K_i = \frac{\sum_{l=1}^{L_i} T_{lw}}{\sum_{l=1}^{L_i} (T_w + T_d)_l},$$

where L_i =number of trips for i -th truck;

T_w =working time of l -th trip for the i -th truck;

T_s = total time (including idle time) of l -th trip for the i -th truck;

-accumulated working time of i -th truck

$$A_i = \sum_{l=1}^{L_i} T_l;$$

-the utilization of the k -th shovel

$$K_k = \frac{\sum_{g=1}^G \sum_{v=1}^V T_{gv}}{\sum_{g=1}^G (T_w + T_s)_g},$$

where $g = (1, G)$ - number of the shovel's working cycles;

$v = (1, V)$ = average number of shovel's buckets to load the i -th truck;

T_{gv} = working time for v -th loading cycle;

-accumulated working time of the k -th shovel

$$B_k = \sum_{g=1}^G \sum_{v=1}^V T_{gv};$$

-need for fuel for the i -th truck

$$Q_i = \sum_{l=1}^L q_l,$$

where q_l = consumption for fuel for the l -th trip;

-need for energy for the k -th shovel

$$E_k = \sum_{g=1}^G q_g,$$

where q_g = consumption for energy of the k -th shovel;

-distribution of energy between machines;

-cost of mining;

-quantity of rock mass that was extracted from various places in a deposit;

-placement of each person at mine;

-working time of each person at mine.

Thus, an on-board medium source must keep the following information about a truck (table 1).

<i>Information</i>	<i>Regularity</i>	<i>Use for mine planning</i>
ID of a truck	Shift	All trucks on the open pit mine
ID of a truck's driver	Shift	Assigning of a driver to a truck
State of a truck	Every hour	Utilization of a truck
Quantity of fuel inside a truck's tank	Every hour	Need for fuel for a truck
Working time of a truck	Current	Accumulated working time for maintenance
Load of a truck's body	Every trip	Accumulated quantity of extracted rock mass
Place of dumping	Every trip	Distribution of rock mass between a refinery, storage, and wastes
Number of a trip	Every trip	Comparison of a trucks' utilization

Table 1. Information about a truck

Other mobile objects, such as a drilling machine, must store and transfer various information for a dispatcher (at least the ID of a machine, its placement, its condition, and duration of its work). Current information about the placement of each working person is necessary for efficient management of the open pit mine.

2.2 Underground coal mining

The most widespread technology of coal mining is shown on the Figure 3.

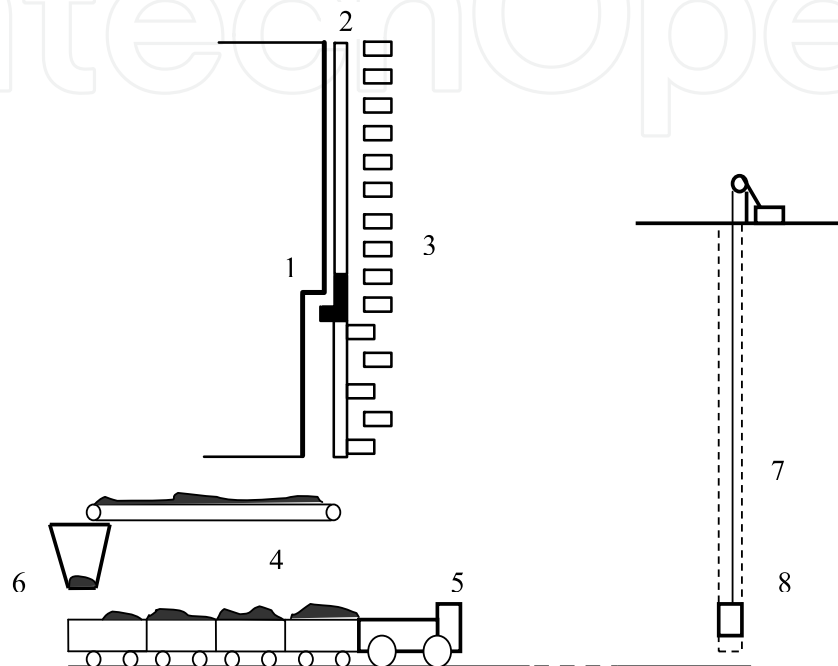


Fig. 3. Technology of coal mining at a fully - mechanized face

A shearer (1) extracts a strip of coal, moving on a metal conveyor (2). At the same time, support units (3) are drawn up a face. The metal conveyor delivers extracted coal to a conveyor network (4). An underground train (5) is loaded under a bin (6). After loading, an underground train transports the coal to a shaft (7). Then the coal is lifted by a skip (8) to the surface.

Many underground roadways for ventilation and transportation are inside an underground mine. Some of them are abandoned, some roadways are in development. All roadways form an underground network.

At present, some information about current work is transferred by a team-leader by telephone. Objective information in real time will improve mine planning (table 2).

Planning at the mine will be more effective because new information can be acquired on the basis of the initial data:

-utilization of *j*-th mobile machine at *i*-th face

$$K_j = \frac{\sum_{g=1}^G T_{wg}}{\sum_{g=1}^G (T_w + T_s)_g} ,$$

<i>Information</i>	<i>Regularity</i>	<i>Use for mine planning</i>
ID of the i -th ($i=1; n$) face	All the time	State of the mine
State of the i -th ($i=1; n$) face (work, stoppage)	Every hour	Re-distribution of faces
Quantity of coal, that was extracted out of the i -th face	Every shift	Comparison of faces, output of the mine
State of k -th machine (work, stoppage or breakage)	Every hour	Utilization of j -th mobile machine, timely repair
State work, stoppage, breakage of k -th stationary machine	Every hour	Utilization of k -th stationary machine, timely repair
Grade of the bin's filling	All the time	Utilization of the bin
Placement of the underground train: on the way to the dumping place, on the way to the loading place, in front of the dumping place, in front of the loading place	All the time	Control of transportation
Condition of the underground train: under a loading, under a dumping, movement, waiting, breakage	All the time	Control of transportation
ID of each miner during the working shift for the i -th face	Twice in the shift	Calculation of working time, identification in cases of accidents
ID of each miner in the various places of the mine	Twice in the shift	Calculation of working time, identification in cases of accidents
Placement of miners in the mine	Every hour	Calculation of working time, identification in cases of accidents

Table 2. The initial data about underground coal mining

where $g = (1, G)$ -number of the machine's working cycles;

T_w =working time in g -th working cycle;

T_s = total time (including idle times) of the g -th working cycle;

-utilization of k -th stationary machine at i -th face

$$K_k = \frac{\sum_{g=1}^G T_{wg}}{\sum_{g=1}^G (T_w + T_s)_g},$$

where $g = (1, G)$ -number of the working cycles;

T_w =working time for the g -th working cycle;

T_s =total time (including idle times) of the g -th working cycle;

-accumulated working time of the j -th mobile machine

$$A_j = \sum_{g=1}^G T_{wg} ;$$

-accumulated working time of the k -th stationary machine

$$A_k = \sum_{g=1}^G T_{wg} ;$$

-need for energy for the i -th face

$$Q_i = \sum_{k=1}^K q_k + \sum_{j=1}^J q_j ,$$

where K = number of stationary machines in the i -th face;

J =number of mobile machines in the i -th face;

-distribution for energy between faces;

-time-table of trains' movement,

-load of a train,

-number of trains for each placement of mining

-cost of mining;

-quantity of rock mass, that was extracted out of various places of a deposit;

-working time of each person at the mine.

Managers of the mine will be able to organize mining at a minimum cost.

2.3 Underground ore mining

The widespread technology of ore mining by extraction chambers is shown in the Figure 4.

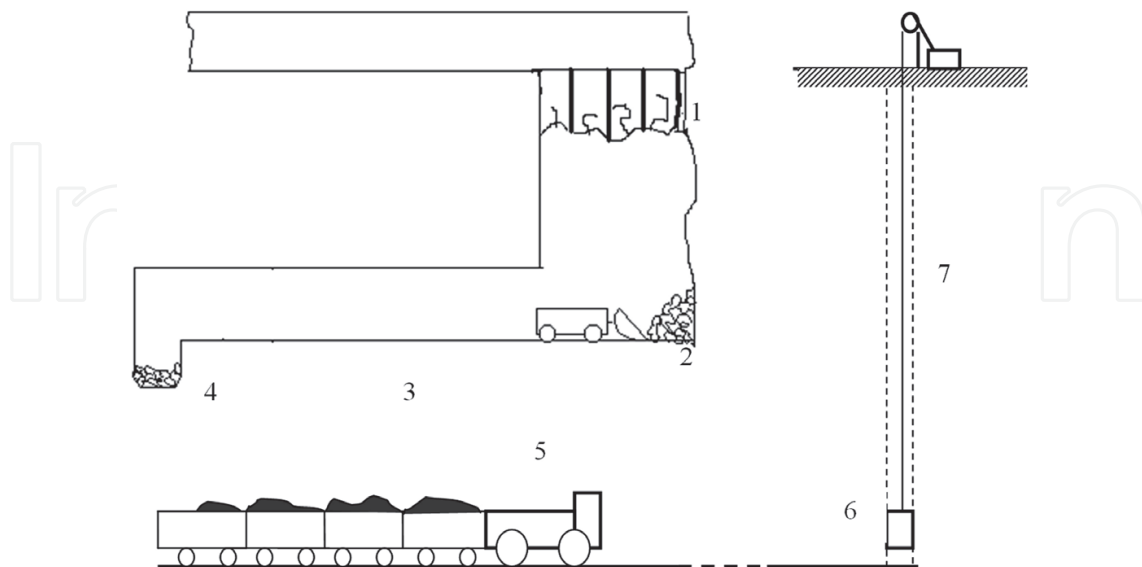


Fig. 4. Underground mining at an ore mine: 1- a roadway for ventilation and drilling machine; 2- a loading-haulage-dumping machine (LHD); 3- a roadway for transportation by LHD; 4- a dumping place; 5- an underground train; 6- a skip for lifting of rock mass; 7- shaft.

First, many vertical boreholes (40-60 meters long) are drilled from a drilling roadway (1) (Fig. 4). Then the boreholes are charged by explosive partially. After the blasting the ore mass drops to the bottom of a chamber. After that, a diesel Loading-Haulage-Dumping machine (LHD) (2) scoops the rock mass and transports it via roadway (3) for a distance 50-100 m to a dumping place (4). Finally, an underground train (5) transports the ore mass to the shaft (7). The rock mass is lifted by skip (6) to surface for refinery. A percentage of useful mineral for a chamber is variable. As a rule, one is known before.

The problem is- how to distribute extraction between the chambers to ensure the given percentage for ore mass on output of the mine. All of mobile machines are attached to the chamber. A behavior of a chamber without extraction is unpredictable.

The following data can be extracted during current work of the mine (table 3).

After preparation of the initial data, a manager of the mine can determine:

-utilization of i -th LHD-machine for the j -th extraction chamber

$$K_i = \frac{\sum_{g=1}^G T_{wg}}{\sum_{g=1}^G (T_w + T_s)_g},$$

where $g = (1, G)$ -number of the machine's working cycles;

T_w =working time in g -th working cycle;

T_s = total time (including idle times) of the g -th working cycle;

-utilization of k -th train

$$K_k = \frac{\sum_{n=1}^N T_{wn}}{\sum_{n=1}^N (T_w + T_s)_g},$$

where $n = (1, N)$ -number of trips for k -th train;

T_v =working time for the n -th trip;

T_f =time of the n -th trip;

-accumulated working time of the i -th LHD-machine

$$A_i = \sum_{g=1}^G T_{wg}$$

-accumulated working time of the k -th train

$$A_k = \sum_{n=1}^N T_{wn};$$

-need for fuel for the i -th LHD-machine

$$Q_i = \sum_{g=1}^G q_g,$$

where q_g =fuel consumption for g -th trip of i -th LHD-machine;

<i>Information</i>	<i>Regularity</i>	<i>Use for mine planning</i>
ID of the i -th ($i=1; n$) mobile machine	Start of the shift	Consideration of machines,
ID of the driver on i -th ($i=1; n$) mobile machine	Start of the shift	Consideration of drivers, permission for driving
Placement of the i -th ($i=1; n$) mobile machine	All the time	Control of mining
State of j -th mobile machine: work, stoppage or breakage	All the time	Utilization of the machine
State (work, stoppage, breakage) of k -th stationary machine	All the time	Utilization of the machine
Quantity of rock mass that was extracted out of a j -th chamber for the trip of the i -th ($i=1; n$) mobile machine	Each trip	Output of the i -th ($i=1; n$) mobile machine
Quantity of rock mass, that was delivered to a dumping place after a trip of LHD	Each trip	Calculation of rock mass
Total quantity of rock mass that was extracted out of a j -th extraction chamber	Finish of the shift	Output of the mine
Grade of the bin's filling	All the time	Utilization of the bin
State of the underground train : loading, movement to the shift , movement to the bin , dumping, breakage	All the time	Utilization of the train
ID of a miners in the various places of the mine	Start and finish of the shift	Calculation of working time, identification in case of accident
Placement of miners in the mine	Every hour	Calculation of working time, identification in case of accident
ID of a miners in the j -th face	Start and finish of the shift	Calculation of working time, identification in case of accident
Quantity of explosive that was expended for the j -th extraction chamber	After blasting	Need for materials
Percentage of dangerous gases inside the j -th extraction chamber	All the time	Danger warning
Placement of the underground train: on the way to the dumping place, on the way to the loading place, in front of the dumping place, in front of the loading place	All the time	Control of transporting
ID of the train on the mine	Start of the shift	Utilization of the train
State of the underground train: under a loading, under a dumping, movement, waiting, breakage	All the time	Control of transporting
Volume of fuel for i -th ($i=1; n$) mobile machine	All the time	Need for fuel for the i -th ($i=1; n$) mobile machine

Table 3. The initial data about underground ore mining

- distribution for fuel for LHD-machine between places of extraction;
- time-table of train movement,
- load of a train,
- dynamics of rock mass extraction out of the j-th extraction chamber;
- number of trains needed for each place of mining;
- cost;
- quantity of rock mass extracted from various places in a mine;
- working time of each person at mine.

As a result, the more effective work, e.g. a redistribution of LHD-routes can be organized according to the concentration of desirable minerals in various places of the deposit.

2.4 Delivery of supplies to distributed underground faces

The distributed faces need the various supplies from the surface to continue mining. At present, a number of supplies loads, such as support units, are delivered from surface storage to a face with the aid of a shaft dropping, transporting by underground rail train, and transporting by winches (Fig.5).

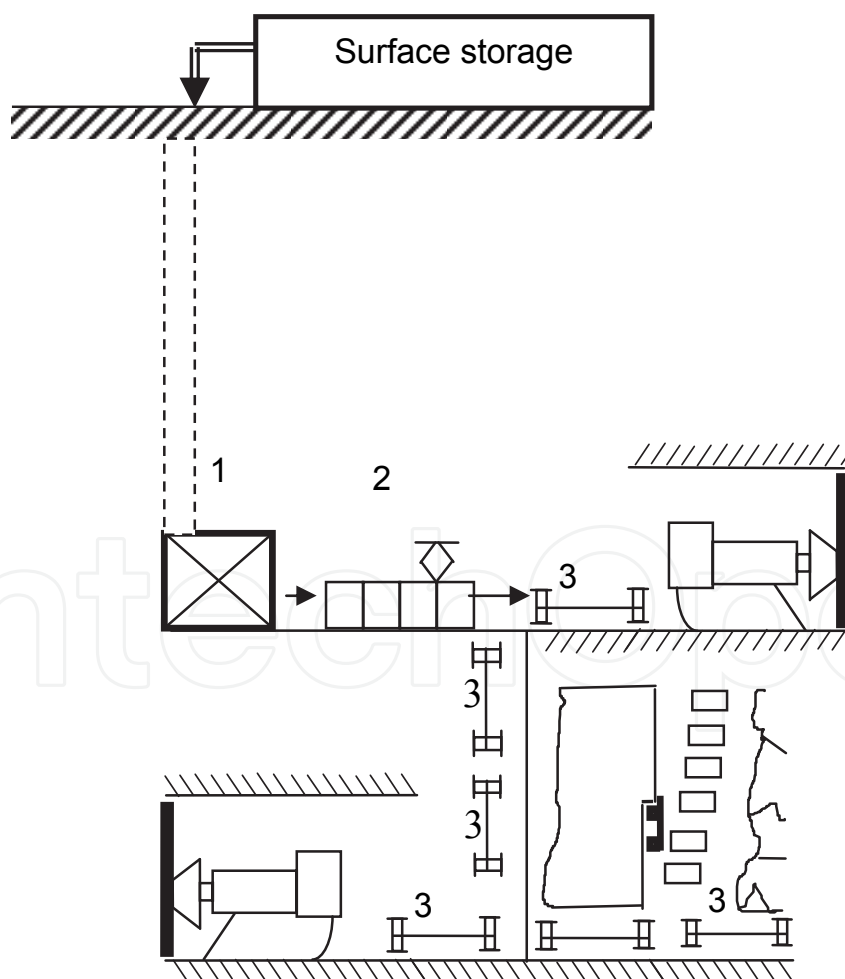


Fig. 5. Existing delivery of loads to distributed faces: 1- underground storage; 2-rail train; 3- winches

The disadvantage of such delivery is the long delay in delivery of supplies to a face. Besides, subjective mistakes for distribution of supplies between faces take place. Underground faces move all the time. A limited space and movement of a face do not permit to have an own storage for a face. Equipping of supplies by medium sources makes it possible, to ensure a face by necessary supplies in "Just-In-Time"- mode (Krieg, 2005).

3. Mobile objects in mining

Moving mine faces require mobile objects. Let's describe some peculiarities of such objects from the point-of-view of mine planning.

It is necessary to know where each miner is in real-time. Consequently, each miner must have an ID. Many ID-readers must be distributed on the pathways miners and connected to the surface via an information network. Mine machines and dangerous places must determine the ID of a miner. Every miner must wear a helmet (hard hat) (Fig. 6).

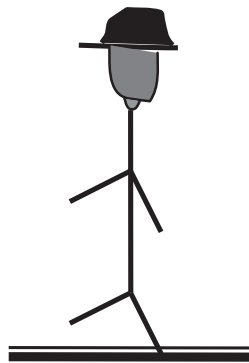


Fig. 6. A miner as a mobile object for mine planning

A helmet is the most suitable place for a medium source that must be cheap, light, and stable to harsh environment. Its capacity may be small. A mine has up to 1000 miners. In underground mining, every miner has a lamp with a battery pack in addition to a helmet.

A truck moves on the fixed road during surface mining (Fig.7). To make a decision about a distribution of trucks, a dispatcher would like to know ID of a machine, ID of a driver, a fuel need, time of loading, movement, and dumping, start and finish points of movement, current load, and placement on a pit mine, and state of a truck. A medium source will work in harsh conditions, with natural temperature, under metal environment. An open pit mine has until 50 trucks.

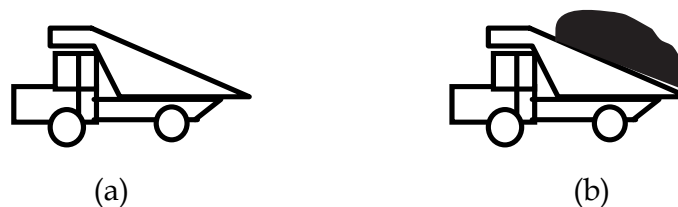


Fig. 7. A truck for surface mining: a- without rock mass; b- with rock mass

There are many mobile machines for underground mining, such as a Loading-Haulage-Dumping Machine (Fig. 8).

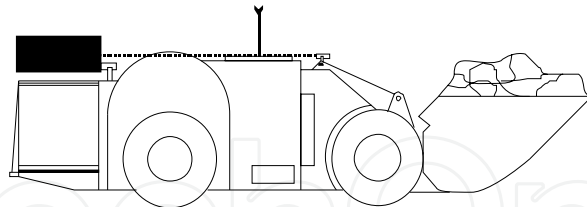


Fig. 8. Loading-Haulage-Dumping Machine as an example of mine machine for underground ore mining

An underground mine has up to 50 such machines. As a rule, a Loading-Haulage-Dumping machine has a diesel drive and rotating bucket.

A surface dispatcher would like to know ID of the machine, ID of the driver, current fullness of the bucket, the fuel need of each truck, current placement and state of each machine, time for each trip. An on-board medium source should work in metal environment and harsh conditions.

4. Identification of mobile objects

Like identification of mobile objects in industry, such decision is the obvious application of miners' identification (Wilma's, 2009). A miner has an own transponder, that is placed on a miner's helmet or on a battery pack (Fig. 9).

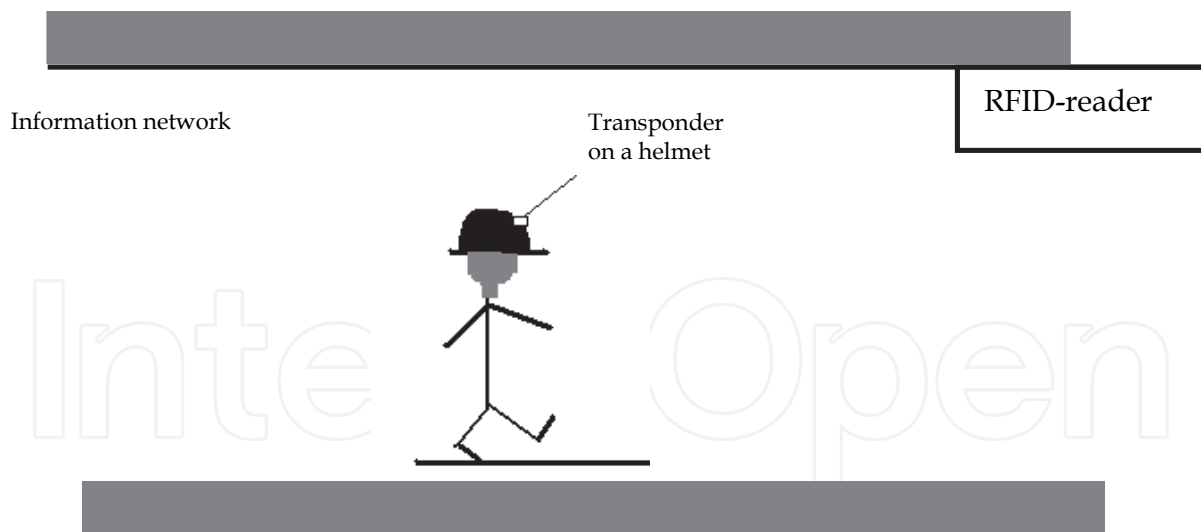


Fig. 9. Identification of a miner

A transponder can be used for identification of other mobile objects. ID of an object is written into a transponder. Stationary RFID-readers with RFID- antennas are connected with the information network and placed in various points of a working zone. If a mobile object moves near an RFID-antenna, the data about his ID and placement have been introduced into the information network (Fig. 10).

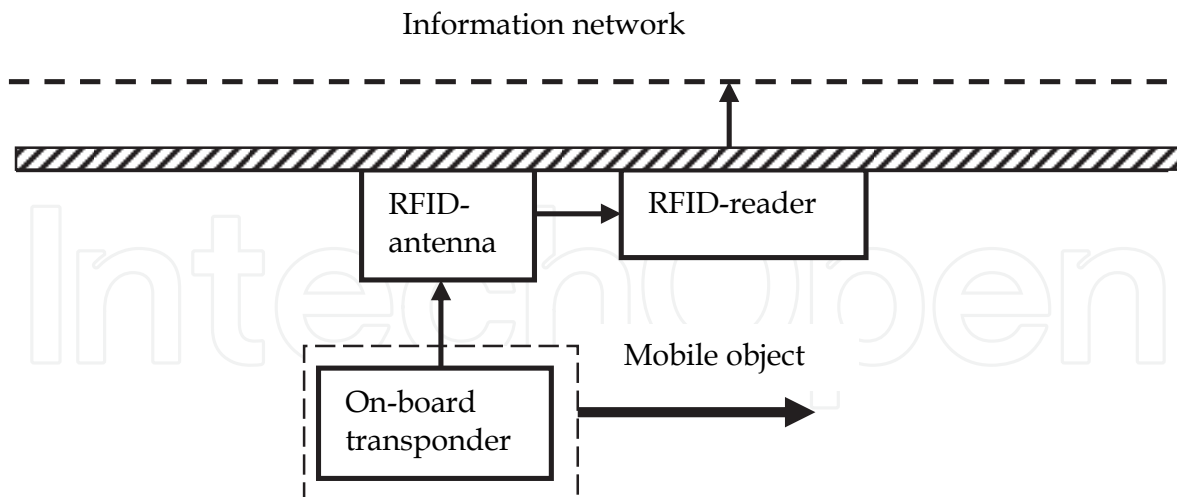


Fig. 10. Information accompaniment of a mobile object

It makes it possible to determine the time of arrival to working place; time of work's finish, placement of a miner at present; give permission for control of a machine.

Additional information can be derived on the basis of the data:

- how long did each miner work?
- where is a miner after his shift?
- how long was each machine used?
- by which miner was driven each machine?
- was access to the machine permitted for the miner?
- who is left in an emergency zone at present?

This information makes it possible to discover the placement of any miner, calculate his working time, and identify a miner in case of accident. The decision could be applicable also for other mobile objects in mining (Spadavecchia, 2007). An RFID-reader can read a vehicle's ID and switch a color-light signal in front of a crossroads. Many RFID-readers on the way of a vehicle can form its route.

5. Requirements to medium sources for mine planning

Many peculiarities of mining make special demands on medium sources.

A transponder for surface mining will be able to work in a natural temperature ranging from -50°C up to $+50^{\circ}\text{C}$. A transponder for underground mining will be able to work in a temperature ranging from 0°C up to $+50^{\circ}\text{C}$.

Mostly an underground roadway is up to 4 meters wide. That is why the distance between a mobile object and an antenna is up to 3.5 meters. The same distance is required for surface mining.

Mine environment is especially damp, dusty, and dirty. An on-board medium source will be able to work in metal environment with electromagnetic violence.

Mostly mobile machines work individually. That is why anti-collision prevention is necessary for miners mainly. However, sometimes it is necessary to determine, how many machines are situated together, e.g. inside a repair shop.

A transponder to identify a mobile object must keep information about the ID of the object only. It is enough to have a capacity app. 1 Kb.

A storage capacity to add information about current mining must be up to 200 Kb. Such information will be written up to 100 times per shift and will be kept at least for one month. The speed of mobile objects during underground mining is up to 1 meter per second. The data for mine planning are mostly constant. The distance between distributed stationary readers must be app.50 meters. The information network must be applicable for many readers, which could be work at the same time.

There are app. 150 mobile machines at a mine. A mine machine has the high cost. That is why; an on-board medium source can be expensive also. The information in a transponder must be protected against non-permitted access and non-permitted rewriting to avoid intentional falsification. A transponder in front of an emergency zone must be intended not only for a miner, but also for a mobile machine.

The acquired information must be complete to reduce cost, close down exhausted areas of deposit and mine new areas of a deposit, stabilize the percentage of useful mineral for a customer, plan the maintenance of mine machines, determine requirements of machines for development of mining, and etc.

6. A mobile mine machine as the data medium

If a mobile machine has an on-board RFID-writer and other mobile objects have on-board transponders, one can determine the way to continue a movement at underground crossroads, determine a miner or another machine in front of the location the mobile machine. It is difficult to get data out of moving working places. A mobile machine with an on-board sensor, transponder, and RFID-writer is suggested by the data on current mining. There are no limitations for the transponder's size.

We suggest using a mobile machine with RFID-writer that writes current information from an on-board sensor to an on-board transponder (Fig. 11).

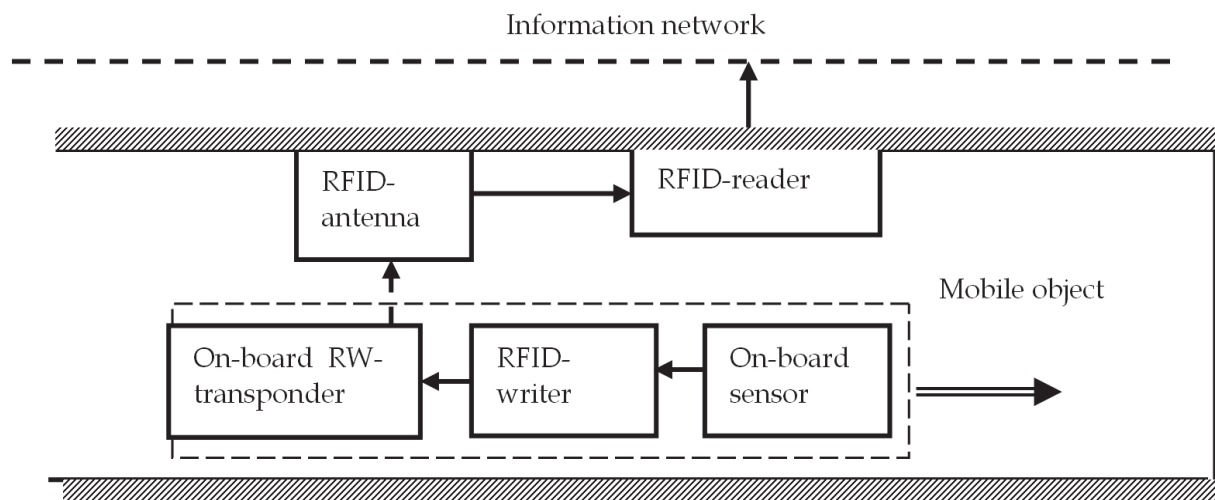


Fig. 11. Delivery of underground information from a mobile object to RFID-reader

A stationary RFID-antenna is placed on a wall of the roadway. The information from a mobile object is transferred to the RFID-reader, and then is introduced to the information network, which connects the distributed moving medium sources with an information centre on the surface (Fig. 12).

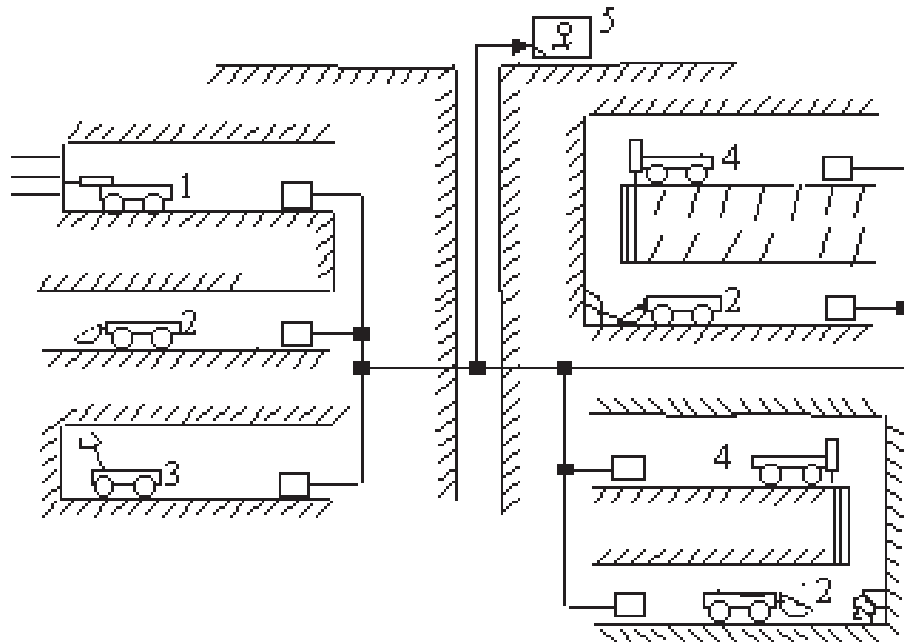


Fig. 12. Connection of underground RFID-readers with an information centre 5 on surface: 1-drilling machine; 2- loading-haulage-dumping machine; 3- shotcreting machine; 4- charging machine

The on-board RW-transponder can collect the data of various sensors to read not only current information but also track that accumulate a quantity of extracted rock mass. Besides, one must keep track of the ID of the various machines.

7. Reliability of primary information

To transfer primary information about current mining, a reliable information network must be introduced. Methodology of the volume balance can be used to have reliable information for mine planning.

$$\sum_{i=1}^m a_i = \sum_{j=1}^n b_j ,$$

where $\sum_{i=1}^m a_i$ = quantity of rock mass, that was extracted out of m distributed faces; $\sum_{j=1}^n b_j$ = quantity of rock mass, that was delivered to storages of mine.

This is estimated on the condition, that extracted rock mass has no addition or loss on the way to a dump.

Besides, the time from between the start of work at a face and appearance of each load at a dump must be calculated and compared with real time.

8. Total planning of mining for the mine

The structure of mine planning can be compared to a manufacturing planning. “Computer Integrated Manufacturing” is a plant that fulfills some orders of customers. One consists of

standards “Manufacturing Resources Planning,” “Manufacturing Execution System,” “Supervisory Control And Data Acquisition,” “Control,” and “Input/Output” (Knuth, 2005). All standards are exchanged by information in real-time.

“Computer Integrated Mining” consists of “Mine’s Resources Planning,” “Mining Execution System,” “Supervisory Control And Data Acquisition”. Two lower standards “Input/Output” and “Control” are necessary for control only.

At first, orders for useful minerals are analyzed by management of mine on the standard “Mine’s Resources Planning” (Fig.13).

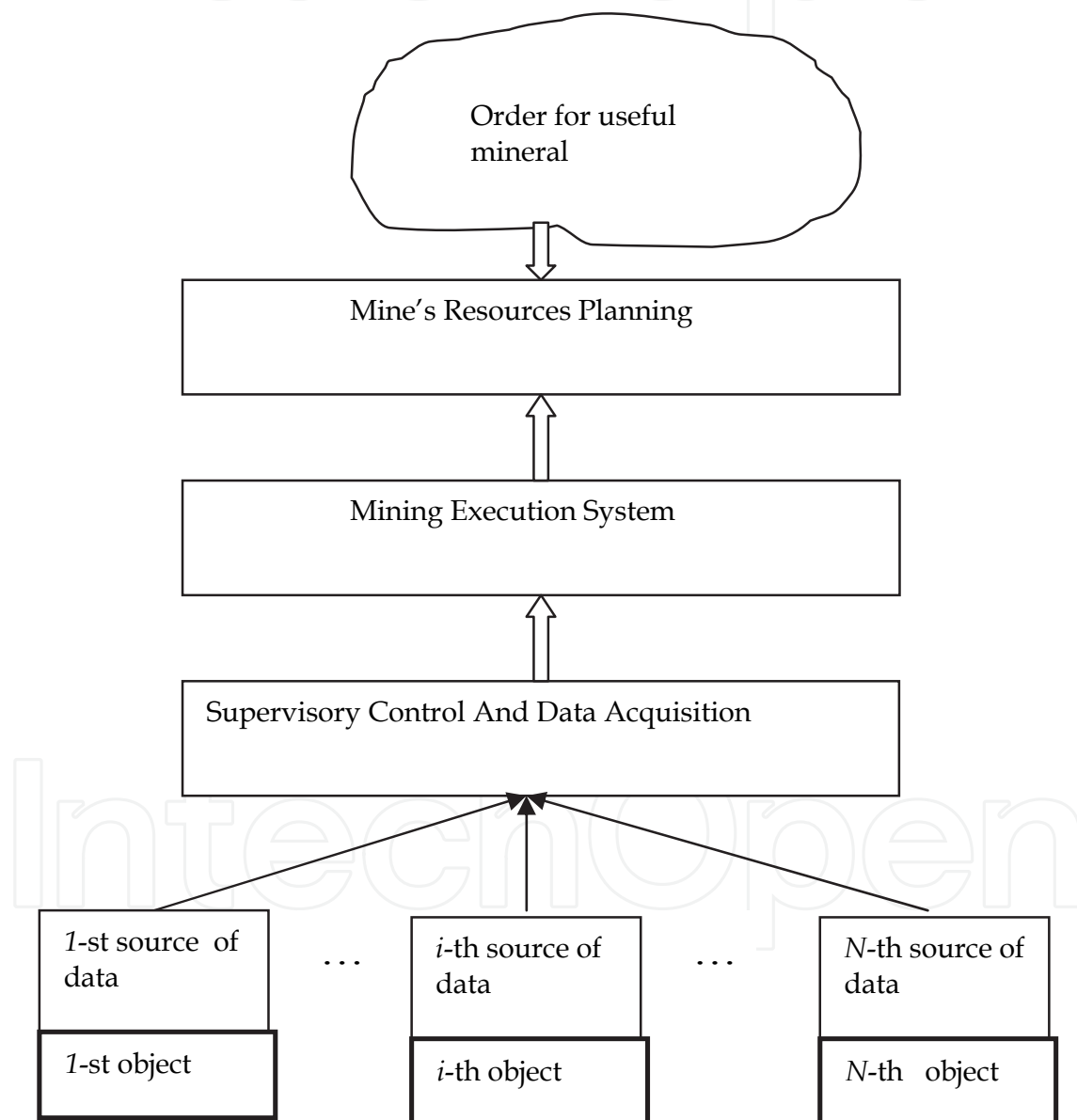


Fig. 13. Standards of mine planning

Managers on the standard “Mine’s Resources Planning” evaluate the potentiality of the mine to fulfill a received order. They plan the development of the mine: existing places,

abandoned places, and new places for mining. In addition, managers plan a changing of a machine, maintenance of mine machines, need for energy, need for materials, need for labor, etc. Decision-makers need various information about current mining (table 4).

<i>Information</i>	<i>Regularity</i>	<i>Effect for mine planning</i>
Current places of mining	A month	Evaluation of current state of mining
Abandoned places of mining	A month	Control of abandoned places
Perspective places of mining	A month	Development of the mine
Percentage of ore in extracted rock mass	A shift	Preparation of a refinery, discharge of a customer's order
Energy consumption for distributed places	A shift	Planning of need for energy sources
Distribution of materials consumption	A shift	Order of materials for distributed working places
Cost of mining	A month	Comparison with the current cost
Accumulated working time of a machine	Time of a working cycle	Planning of a energy consumption, maintenance, and replacement of a machine
Accumulated working time of a miner	A shift	Calculation of earnings
Orders of distributed places for materials	An hour	Distribution of materials

Table 4. Information for the standard "Mine's Resources Planning "

Energy consumption for *j*-th place of mining is calculated automatically as

$$E_j(T) = \sum_{i=1}^n E_i(T),$$

where $E_i(T)$ = energy consumption by *i*-th machine for the period *T*; *n* = number of machines for *j*-th place of mining.

Need for *k*-th kind of materials (explosive, cables, pipes, etc.) for the mine is calculated as

$$S_k(T) = \sum_{j=1}^m \sum_{k=1}^K S_{jk}.$$

Plans for the mine should be corrected according to current orders out of distributed faces. Cost of mining is summarized as the share expenditures on working powers, energy, materials, amortization, etc.

Accumulated working time of a machine is necessary to replace machines workout:

$$T_i = \sum_{p=0}^w t_p,$$

where *W* = summary working time of *i*-th machine.

Accumulated working time of α -th miner is necessary to determine the earnings of α -th miner:

$$P_{\alpha} = \sum_{i=0}^F (p_i \times n) ,$$

where p_i = hour's earnings of α -th miner; $n = (0;F)$ = number of working hours for α -th miner. Analyzing current information about the activity of the mine, a manager is able to re-distribute the mobile machines between places of mining, re-distribute teams of miners for a working shift, change the faces according to a current order, re-distribute the working shifts, etc.

9. Reflection of current mining

It is necessary for a dispatcher, to observe the current activity in a mine. To realize it, a Supervisory Control And Data Acquisition (SCADA system) is used. The existing SCADA-packages, such as In Touch®, can be adapted to the mine. The self-designed SCADA-system can be developed for the mine also. The development of the own SCADA-system is cheaper, but depends on developers of the mine.

There are static and dynamic information about current mining. Static information consists of the plan of the mine; the placement of stationary equipment, network of communications, placement of faces, some inscriptions. Dynamic information consists of current data about the mine: the state of any face (work or idle time), output of any face, state of any mobile object, current placement of any mobile machines; fullness of any bin. For example, the open pit mine is presented on a screen (Fig. 14).

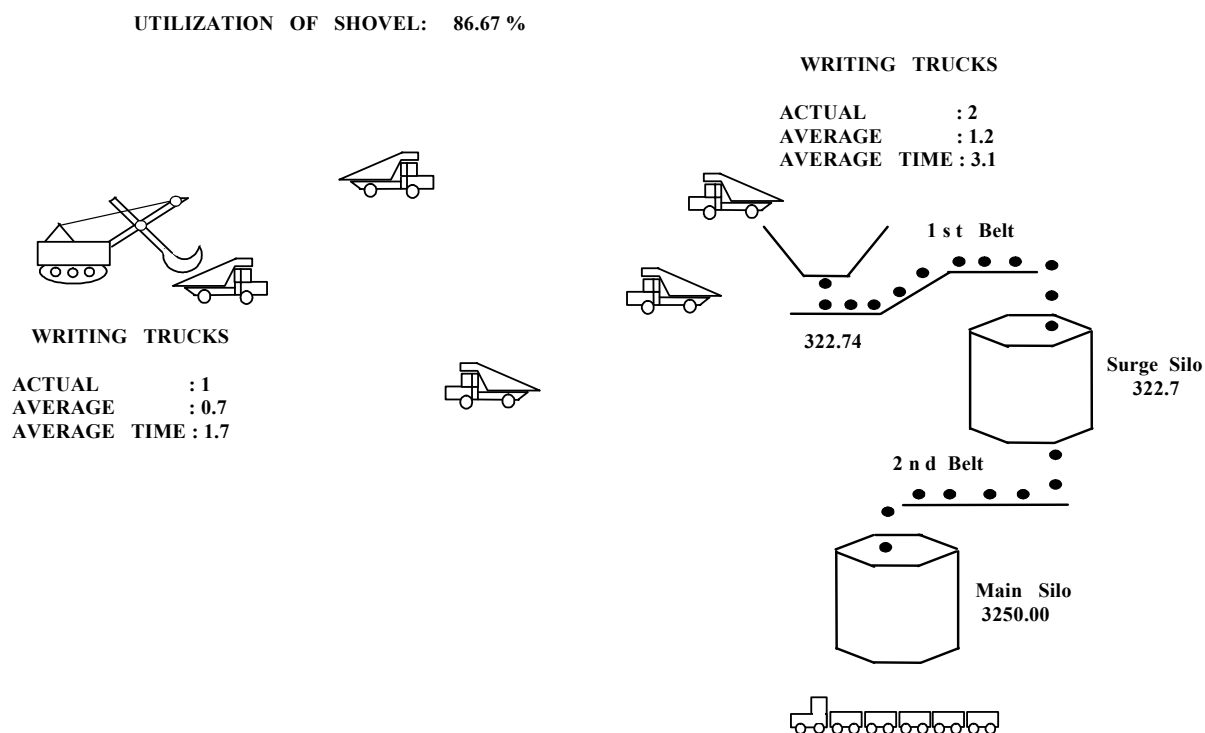


Fig. 14. Reflection of the open pit mine in USA (Sturgul, 1995)

Static information is the placement of shovel, silos, belts, railway, and inscriptions. Dynamic information is placement of trucks, state of the shovel, number of empty and loaded trucks, utilization of the shovel, time of the trip, filling of the silos, and load of the belts.

At first, static information must be constructed on a dispatcher’s screen (table 5).

<i>Information</i>	<i>Details</i>	<i>Accuracy</i>
Scheme of the mine	no required	± 10 m
Places of loading	no required	± 10 m
Places of unloading	no required	± 10 m
Network of existing faces	no required	± 10 m
Network of abandoned faces	no required	± 10 m
Network of communications	no required	± 10 m
Transport network	no required	± 10 m
Placement of the stationary machines	no required	± 10 m
Various tables	standard	standard
Various inscriptions	standard	standard

Table 5. Static information for a dispatcher’s screen

Then dynamic information about current time, output of the face, current plan’s execution, pre-recognition of future accidents, and support of operative decisions in case of accidents is presented on a screen in real-time mode (table 6).

<i>Information</i>	<i>Regularity</i>	<i>Reflection</i>
State of a face	Every hour	Color of a face
Distribution of mobile objects	Every 15 minutes	Placement on the network
Output of a face	Every hour	Current data
Time of a working cycle	Each working cycle	Data
Output of the part of the mine	Each shift	Data
Fullness of every bin	Every 15 minutes	Full part of bin
State of the transport machine	Each trip	Color of a machine

Table 6. Dynamic information for visualization of current mining

Information is changed on a dispatcher’s screen by introduction of global variables (by tags). Connection of medium sources with virtual reflection of mining is realized using OLE for Process Control (OPC).

The main rule for visualization is that the information must be enough to make a decision about improvement of current mining. For example, a decision-maker can compare the activity in various places of the mine.

Watching current mining information, a dispatcher can step and call the concrete persons, such as a team’s leader to clear the matter up. The SCADA-system recognizes pre-accident situations in good time and notifies about beginning violations in normal work of the mine. If a random accident takes place, the SCADA-system produces recommendations to a dispatcher, who can prevent a deterioration of the situation, e.g. localize a random fire in various places of the mine.

As well as current information, the SCADA-system keeps detailed information about past mining, such as utilization of a mine machine. Comparison of current information with former information can improve the current mining.

Using this system, the information about total working time, expenses of energy, total output, utilization of mobile objects, and utilization of bins can be acquired for managers of the mine.

10. Mining execution system

The system is geared to control execution of shift planning and prepare information for the standard "Mine's Resources Planning".

Sometimes mine equipment units have failures. Breakages lead to random refusals of a total technological chain.

Mining Execution System (MES) redistributes the faces and mine machines to ensure the same output of mine. The standard needs current information about mining (table 7).

<i>Information</i>	<i>Regularity</i>	<i>Effect for mine planning</i>
Output of a face	All the time	Contribution of a face to the mine's output
State of a face	All the time	Re-distribution of mining's places
Working time of a face	All the time	Fulfillment of a face's plan
State of a machine	All the time	Control of mining
Working time of a machine	All the time	Planning of maintenance
Placement of a machine	All the time	Planning of mining
Placement of miners	All the time	Planning of miners' distribution
Working time of a miner	All the time	Evaluation of miner's use
Fulfillment of a mine's plan	All the time	Evaluation of plan's fulfillment
Real time	All the time	Evaluation of the shift's time

Table 7. Information for "Mining Execution System"

Using this information, a mine dispatcher can determine how to maintain output during of unpredictable situations.

11. Suitability of RFID for mine planning

Optical character recognition needs comparison with a model. Random forms of objects, such as surge pile of rock mass make this impossible for mining. Infrared identification is not applicable for mining, because there is limited potential for a changing environment, requires the line of sight between a transmitter and receiver of information, needs comparison with a pattern. Bar coding has no protection to soiling and can not be attached by new information.

As a rule, voice sources of information are in use for mine planning. Voice sources are non-exact and non-reliable for mine planning.

Mobile data mediums on the basis of RFID produce many opportunities for mine planning. RFID-system can work under the harsh mine environment and does not require the light-of-sight between a transponder and a writer. Active transponders can be read at great distances. It is an obvious use of an RFID-system for identification and positioning of mobile objects.

Some mines introduce RFID to identify miners (RFID for Mining, 2008), like identification of goods in commerce. Many transponders can be read at once. Nobody can avoid being identified before work. RFID-systems present the data in real time. It is impossible to forge information inside a transponder.

The possibility exists to add information and use machines to deliver data about working places in real time. Active transponders for mine applications may be smart. RFID-systems have no moving parts and do not require regular maintenance.

However, all miners must be informed in case of an accident. RFID may not be used to transfer accident information. The special design of RFID-system for a metal, dirty, and dusty environment is necessary. A mine must be equipped with an information network. Underground mines for coal mining require special permission to use RFID-system in an explosion-dangerous environment.

12. Towards intellectual mining

Deposits of useful minerals that were easily accessible for traditional mining are exhausted already. Historically, an underground mine is dangerous and unpleasant for miners. At present, the average depth of mines is 1200 meters. The deeper a mine is, the worse and more dangerous miners' work is and the more expensive miners' work is. The high temperature of the Earth's centre raises the temperature of the underground mine and it will be impossible to work.

It is too hard to co-ordinate underground mining actions in space and time. There are idle times of underground equipment owing to inadequate information about current mining. Employers waste a lot of money transporting miners for underground work.

The long-term dream of mining engineers is to be able to mine without underground miners. The main idea is - the control of underground machines from the surface (Fig. 15).

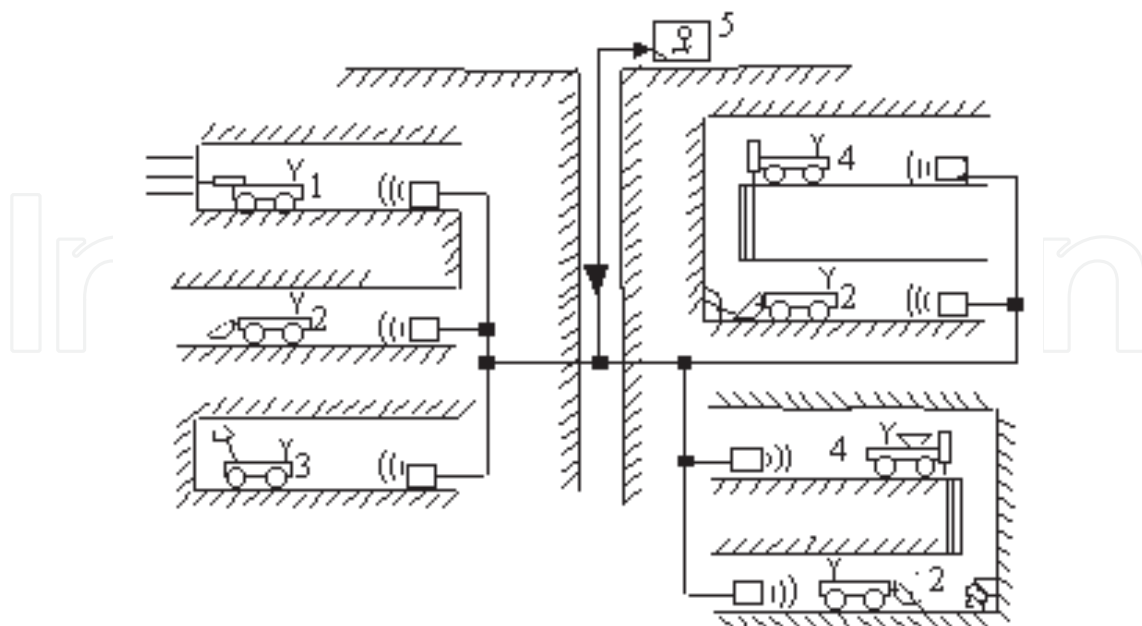


Fig. 15. Underground mining without underground drivers: 1-drilling machine; 2- loading – haulage-dumping machine; 3- shotcreting machine; 4- charging machine; 5- drivers' box

A console for remote control is situated in front of a working place. One is connected via an underground information network with the driver's box on surface. Mobile mine machines move along a guideline, which is placed in roadways. A driver observes a working place as if he is on a machine and transfers control commands to the machine. Each of the mine machines is equipped with an on-board receiver.

A broadband information network is the backbone of future mining. Such a network must transfer video, audio, and data information from distributed working places to the surface and back.

A machine in intellectual mine can adapt itself to changing working conditions: to change positions of working heads, direction of movement, step size of a roof support, and speed of a roof support. Such opportunities will make it possible to avoid some geological hazards, avoid dangerous rock pressure manifestations, stabilize the quality of mining, and increase the utilization of machinery. Existing information networks for voice exchange is not available for intellectual mining because the control of an autonomous machine in real-time needs a broad transmission band for video information.

Information network for a future mine could be used not only for remote control of underground machines, but also for mine planning using RFID.

As the long-term, an RFID-system for mining on other planets without direct visibility of a working place can be created.

13. System approach to use RFID for mine planning

The main idea of system approach consists of the creation of elements for the future system using step-by-step development. Each element will be included in a future system later without changes.

An RFID-system will be included in future mining that is based on control without direct visibility. How to transfer current information about mining to management of the mine? Many distributed working places are moving all the time during mining.

The existing information network in a mine was created for telephonic communication only which has a narrow communication band. Probably, transmission of data information via such a network will be incorrect for future mine planning.

A distributed information network for a future mine must transfer video information in real time mode to a remote driver. That is why one must connect moving transmitters with stationary receivers and be broad-band. Later, the network for future mining will be used for transferring information from on-board transponders without additional expense.

14. Need for research on the way to mine planning using RFID

It is necessary to test the RFID-system for the harsh mine environment that is metal, dirty, dusty, and damp.

An on-board RFID-writer for a suitable mine machine must be selected. One should have input for a sensor and output for the transponder. Existing telephonic network must be tested for suitability to transfer data information from the transponder.

The influence of random electromagnetic interference on RFID-system must be evaluated.

Placement of RFID-writer and RFID-transponder on a mine machine must be carefully chosen. The packages must be developed for each stage of mine planning. A human-machine interface must be developed for the visualization of current mining.

15. Conclusion

Mining has many peculiarities to get reliable information for mine planning. Environment for a data medium is humid, dirty, and dusty. Mine machines are metal. Working places are distributed in a space and move all the time. At present, RFID is used for identification of miners only, like identification of moving goods using EPC.

The connection of a sensor on a mobile object allows an RFID-writer to develop new potential for RFID-applications in mine planning.

Such a mobile data medium allows the gathering of various information: current reports about an extraction in various places of a deposit, placement of mobile objects during mining in real time, avoidance of non-permitted access to control, acquisition of full information about current mining, warning about emergency situations, and etc. An RFID-system can be used to visualize the placement of machines along roadways; to monitor miners with personal transponders; to prevent non-permitted control of machines; to give priority control of machines; to evaluate productivity of both machines and mining areas; to evaluate fuel consumption and machine resources. This information can be used for management of the mine.

16. Acknowledgment

This work is supported by the Russian Foundation of Basic Researches, grant № 10-08-01211-a "Modeling of mining on deep mines" and the State Program "Joining of Science and High Education in Russia for 2002-2006", grant № U0043/995 "Preparation of experts in information technologies for Kuzbass region". Many thanks to my old friends Prof. J.Sturgul and his wife Alison (Australia) for the thorough correction of English text.

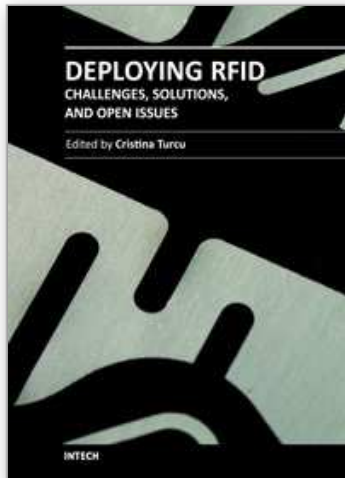
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Deploying RFID - Challenges, Solutions, and Open Issues

Edited by Dr. Cristina Turcu

ISBN 978-953-307-380-4

Hard cover, 382 pages

Publisher InTech

Published online 17, August, 2011

Published in print edition August, 2011

Radio frequency identification (RFID) is a technology that is rapidly gaining popularity due to its several benefits in a wide area of applications like inventory tracking, supply chain management, automated manufacturing, healthcare, etc. The benefits of implementing RFID technologies can be seen in terms of efficiency (increased speed in production, reduced shrinkage, lower error rates, improved asset tracking etc.) or effectiveness (services that companies provide to the customers). Leading to considerable operational and strategic benefits, RFID technology continues to bring new levels of intelligence and information, strengthening the experience of all participants in this research domain, and serving as a valuable authentication technology. We hope this book will be useful for engineers, researchers and industry personnel, and provide them with some new ideas to address current and future issues they might be facing.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Vladimir Konyukh (2011). Mine Planning Using RFID, Deploying RFID - Challenges, Solutions, and Open Issues, Dr. Cristina Turcu (Ed.), ISBN: 978-953-307-380-4, InTech, Available from:
<http://www.intechopen.com/books/deploying-rfid-challenges-solutions-and-open-issues/mine-planning-using-rfid>

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