USE OF SOLUTION STRATEGY IN OPEN CAST MINING TRUCK DISPATCHING SYSTEM

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ABSTRACT: The technique introduced in this paper is based on logical simulation and functional complex models, which will analyze, estimate and optimize the parameters of the open cast transportation system. For this purpose, flexible truck allocation has first been carried out by a goal programming model. The criteria to be optimized are maximization of production while controlling the quality of ore, which is sent to the processing plant. The transportation system has then been simulated by Arena simulator. This simulator and executive software has the advantages of schematic displacing of the real system. In this software, creating a mineral system perspective, determining the location of the equipments and their distances from each other is possible by using appropriate monitoring. The results of simulations have shown that using the proposed allocation technique, a substantial increase in production and productivity of an open cast mine is achieved.

1 INTRODUCTION

Haulage costs in truck-shovel systems constitute a major portion of total expenditures. This means an efficient operation of truck-shovel system is vital. Although unit production cost has been decreased by increasing the capacity and performance of mining equipment, a good management of haulage system can improve a mine's productivity with the same equipment. In a truck-shovel system, the efficient deployment of equipment can minimize the waiting costs of trucks and shovels. In general, trucks wait for the shovel's free time if the system is over-trucked and a shovel has to wait for trucks arrival when the system is under-trucked. To minimize the truck-shovel cost, the optimum number of trucks used in the mine haulage system should be determined for every operation. Also, with a number of shovels of a mine, trucks may be dispatched to shovels, which cause less waiting times. In these cases, the influence of a dispatching system on maximizing the trucks or shovels utility should be studied. Operation research techniques have been used in the past to study truck-shovel system.

In this paper, the offered technique is based on logical simulation and functional complex model, which will analyze, estimate and optimize the parameters of the open cast transportation system. For this purpose, flexible truck allocation has first been carried out by a goal programming model. The transportation system has then been simulated based on input data of goal programming model by Arena simulator. This simulator and executive software has the advantages of schematic displacing of the real system. In this software, creating a mineral system perspective, determining the location of the equipments and their distances from each other is possible by using appropriate monitoring.

2 FUZZY GOAL PROGRAMMING FOR TRUCK ALLOCATION

From the middle 1980s, optimization of truck allocation has been considered as a significant issue for increasing productivity and reducing operating costs of loading and haulage system in open pit mines. There are several models for truck allocation. Use of these models in the mines results an increase in production about 5 to 12 percent (B.Asi, 2004). These systems are usually based on mathematical programming models, which are used to determine a short term mining plan for achieving production and quality targets set by management. In this paper, optimization of transportation system was carried out by Fuzzy Goal Programming model (Oraee & Asi, 2004).

The most important factor in every mining operation is profitability. Productivity of mining component is an important determinate of profitability. Profitability can be increased by optimization of equipment in used. Therefore the first goal in this model is to maximizing productivity and hence increases production, which in turn will result in cost reduction. In metal mines, the ore grade dispatch to the crusher is important and therefore in this model it has constituted the second target. So, the criteria to be optimized are maximization of production while controlling the quality of ore, which is sent to the processing plant. The case study of this model is Songun Copper Mine of Iran. In this mine, truck-shovel system is used for ore and rock transportation. The input data consist of parameters and variable of Songun Model are shown in Table 1.

Table 1. Variable and parameters of Songun model

TECHNICAL VARIABLE			**TECHNICAL VARIABLE**		
Number of Shovels	*Ns*	3	Prescribed upper limit of stripping ratio	*Ru*	5
Number of ore shovels	*Nos*	2	Prescribed lower limit of stripping ratio	*Rl*	3
Number of oxide shovels	*Nxs*	0	Value of ore quality k at source i	G_{ki}	0.759 ,0.657 ,0
Number of lowgrade shovels	*Nls*	1	Target value of ore quality k at crusher j	Q_{kj}	0.73
Number of destinations	*Nd*	3	Prescribed lower limit of ore quality k at crusher j	L_{kj}	0.68
Number of crushers	*Nc*	1	Prescribed upper limit of ore quality k at crusher j	U_{kj}	0.78
Number of oxide dumps	*Nxd*	0	Hours per shift	*Wt*	8
Number of lowgrade dumps	*Nld*	1	Least required ore production per hour	*Fore*	7000
Types of ore quality	*Nq*	1	Least required waste production per hour	*Fwaste*	28000
Number of truck types	*Nh*	1	Prescribed upper limit of stripping ratio	*Ru*	5
Maximum output from shovel i per hour	M_i	2200,2200,2200	**FUZZY PARAMETERS**		
Maximum available capacity of dump/crusher j per hour	C_j	40000,100000,100000	Pessimistic output from shovel i per hour	$O^p{}_i$	1900,1900,1900
Average dumping time at destination i by truck h	D_{jh}	1,1,1	Optimistic output from shovel i per hour	$O^o{}_i$	2200,2200,2200
Average loading time at source i by truck h	S_{ih}	3,3,3	Normal output from shovel i per hour	$O^m{}_i$	450,450,450
Average spotting time at destination i by truck h	SD_{jh}	1,0,0	**COMPLEMENTARY PRAMETERS**		
Average spotting time at source i by truck h	SS_{ih}	1,1,1	Priority factor for production goal	W_1	0.5
Number of truck h	N_h	14	Priority factor for quality goal	W_2	0.5
Weighted average payload of a truck h	T_h	136	Confidence level specified by the decision maker	α	[0,1]

Fuzzy Goal Programming model has been carried out in Songun Copper Mine. Output Volumes obtained from optimizing the model and those produced in the mine are showing in the Table 2.

3 MODELING BY ARENA SIMULATION SYSTEM

Application of a dispatcher in truck-shovel systems and different dispatching rules have been reported by Lizotte, Bonates and Leclerc (1987), Bonates and Lizotte (1988). The major purpose of providing a dispatching system is to maximize productivity of the system. This can be done through procedures such as maximizing trucks or shovels utility. This paper presents a dispatching rule and studies its influence on a mine performance (productivity) using Arena simulation system.

Table 2. Output Report of Songun optimization

Variable	Value	Variable	Value
HT(1, 1, 1)	15.47000	X(1, 1, 1)	6804.791
HT(1, 2, 1)	16.14000	X(1, 2, 1)	8395.209
HT(1, 3, 1)	2.250000	X(2, 1, 1)	3587.981
HT(2, 1, 1)	6.190000	X(2, 2, 1)	7583.108
HT(2, 2, 1)	25.44000	X(3, 3, 1)	15200.00
HT(2, 3, 1)	3.660000	Y(1, 2, 1)	10392.77
HT(3, 1, 1)	5.830000	Y(2, 1, 1)	778.3167
HT(3, 2, 1)	15.29000	Y(2, 3, 1)	15200.00
HT(3, 3, 1)	5.360000	Y(3, 1, 1)	14421.68
R(1, 1, 1)	8.210000	Y(3, 2, 1)	778.3167
R(1, 2, 1)	4.900000	NTX(1, 1, 1)	50.00000
R(1, 3, 1)	4.560000	TX(1, 2, 1)	62.00000
R(2, 1, 1)	8.830000	NTX(2, 1, 1)	26.00000
R(2, 2, 1)	10.18000	NTX(2, 2, 1)	56.00000
R(2, 3, 1)	4.510000	NTX(3, 3, 1)	112.0000
R(3, 1, 1)	2.060000	NTY(1, 2, 1)	76.00000
R(3, 2, 1)	2.890000	NTY(1, 3, 1)	0.000000
R(3, 3, 1)	4.090000	NTY(2, 1, 1)	6.000000
NORMC(1)	1.414214	NTY(2, 3, 1)	112.0000
NORMC(2)	1.414214	NTY(3, 1, 1)	106.0000
NORMC(3)	1.000000	NTY(3, 2, 1)	6.000000
NORMD(1, 1)	0.621E-01	F	41571.09
GRADE(1, 1)	0.7300000	FW	31178.32

HT_{ijh}: Average traveling time of shovel I to destination j by truck h
R_{jih}: Average traveling time from crusher/dump j to shovel I by truck h
X_{ijh}: Feed quantity to assign from source I to destination j per shift by truck h
Y_{jih}: Empty truck capacity to assign from destination j to source I by tuck h

An Arena modeling and executing system has the advantage of using scaled schematic layout of the real system. Using suitable symbols provided by Arena, it is possible to make a layout of the mine system, determine the location of objects and distances, i.e. shovels, dumps and routes. Arena models typically contain at least one source module to create arrivals to the system, and one or more sink modules that model the departure of these entities from the system. However, in a truck-shovel system, entities are only created and do not depart from the system but rather move through the system cyclically (Fig. 1)

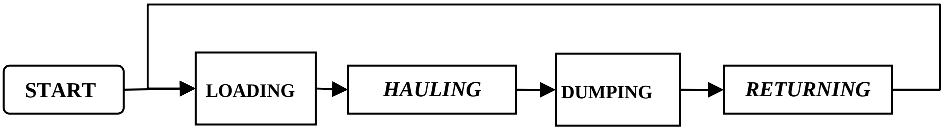

Figure 1. A Typical truck-shovel system model

4 ARENA MODELING TOOLS

The draw panel in Arena may be used to add static graphics and text to the window for different characteristics. Using this tool, various objects of the model may be represented by pictures and saved in a file. The following definitions are required to complete the Arena modeling process (Baafi&Ataee, 1998):

Defining trucks arrival: The fleet size for different simulation runs can be entered interactively by combining *Arrive* module with *Read* and *Duplicate* modules. The *Duplicate* module creates exact replicas of the arriving entity and sends these newly created entities to the specified modules. This module makes it possible to put different numbers of trucks at different shovels.

Defining Servers: There are three other shovels and three dumps that should be represented by the *Server* modules. This implies a total of eight *Server* modules are required to simulate five shovels and three dump sites. Modeling of other shovels and dumps are exactly the same as described previously except for data input requirements. The six *Server* modules used in the system are:

(a) Waste-shovel	(g) Waste-dump
(e) Ore-shovel	(d) Crusher-dump
(b) Lowgrade-shovel	(h) Lowgrade-dump

Stations: *Station* modules are used to represent the truck arrivals, servers and junction points. Each station must be defined by a unique name. A total of fourteen *Station* modules have to be defined in this model, six of which are defined through *Server* modules and one through the *Arrive* module.

Sequencing Stations: Trucks assigned for various shovels have different sequences of station visitation. Similarly, trucks served by other shovels have their own sequences. These sequences can be distinguished by their names and numbers.

Variables: There are some parameters in the system that change during a simulation. Also, it may happen that a parameter is constant during a simulation but the user would like to change its value for different simulation runs, such as the fleet size. This option is provided in Arena by the *Variable* module. The *Variable* module defines user-defined, global variables and their initial value.

Simulation Parameters: The length of the simulation run is one week or fifty six hours. Since the time unit of the system is described by seconds, the length of each replication is to be 201600 seconds. The number of replications was determined as 30 to provide simulation running for adequate combinations of different truck fleets for shovels in the mine.

Statistics Collection: The number of trucks loaded by each shovel, utility of each shovel, the time lost in all waiting queues and the queue length for all shovels are useful statistics that are obtained from a simulation run. Arena provides a module called Statistics, which is used to define statistics that are to be collected during the simulation run. However, many statistics can be collected directly from the modules (for example, *Server* module) that reference the relevant element.

Animation: The system default pictures of entities and resources may be replaced by pictures of trucks and shovels in different status, crusher, dump and stockpile. These pictures were drawn in Arena using Draw tool. Seize area of shovels and dumps are tailored so that trucks are placed in suitable distances under shovels or on the dumpsites. To illustrate the number of trucks in queue for each shovel, Plot and Variable icons are employed in the example model.

5 THE DISPATCHING MODEL

The logic of the model in the dispatching model is as follows. After placing a truck at Arrive module, the total necessary trucks of the system will be determined by Read Module and will be copied in Duplicate Module as required. Then all trucks will enter the Station Module. This module is used for defining the AL Station (junction). After that, all trucks will enter the choose Module, where trucks will be assigned the suitable destination. Trucks may assume one of the following conditions (Damiri, 2005):

1) The truck is empty and shovel is active and ready for work.
2) The truck is empty but the shovel is inactive.
3) The truck is full.

At the first case, the truck will be sent to an Assign Module. This module performs all essential calculations of dispatching. In this module the Expected Capture Time of each truck by shovel (ECT), Expected Release Time by each shovel (ERT) and the waiting time of each truck or Delay in queue of each shovel (DEL) will be calculated. The compute code for the model in Arena is shown in Fig. 2. Then the truck will enter a Pickstation Module. In this Module, the shovel with the minimum waiting time in its queue will be chosen.

The truck enters to an Assign Module, in which the suitable sequence is determined for the truck to arrive at the chosen shovel using a Route Module; the truck is sent to the specified period of time required for returning of the empty truck. The remaining process is like that of non-dispatching mode. If the 2th status occurs, i.e. the truck is empty and the shovel is inactive, the truck will be sent to the Server Module that represents the repair shop. In the 3nd status, i.e. the truck is full, when the truck reaches to the junction, the truck will be sent to the dumping area by using a Route Module. This Module will persuade the truck to spend a period of time equal to the travel time to the next destination. The Modules shown in Fig. 3 are those that are used in the dispatching model.

```
;           Model Statement for module: Assign 1
;
14$         TRACE,                  -1,"-Making assignment \n":;
119$        ASSIGN:                 ECT(1)=FECT(1):
                        ERT(1)=FECT(1):
                        DEL(1)=ERT(1)+NORM(3,0.18):
                        DEL(1)=ERT(1)-(TNOW+NORM(8.21,0.095):
                        ECT(1)=MAX(ERT(1),TNOW+NORM(8.21,0.095):
                        ECT(2)=FECT(2)
                        DEL(2)=ERT(2)+NORM(3,0.18):
                        DEL(2)=ERT(2)-(TNOW+NORM(8.83,0.081):
                        ECT(2)=MAX(ERT(2),TNOW+NORM(8.83,0.081):
                        ECT(3)=FECT(3)
                        DEL(3)=ERT(3)+NORM(3,0.18):
                        DEL(3)=ERT(3)-(TNOW+NORM(2.06,0.201):
                        ECT(3)=MAX(ERT(3),TNOW+NORM(2.06,0.201):
;
; Model statement for module: Pickstation 1
;
15$         TRACE,                  -1,"-Selecting Min of 3 station\n":;
120$        FINDJ,                  1,3:Min(+WHATSHOVEL? PS(4,J));
121$        ASSIGN:                 RETURN=WHATSHOVEL? PS(1,J):NEXT(16$);
;
; Model statement for module: Choose 1
;
16$         TRACE,                  -1,"-Choosing from 3 options\n":;
126$        BRANCH,                 1:
                        If, RETURN==OS1,17$,Yes:
                        If, RETURN==SS,18$,Yes:
                        If, RETURN==OS2,19$,Yes:
```

Figure 2. A dispatching model in ARENA

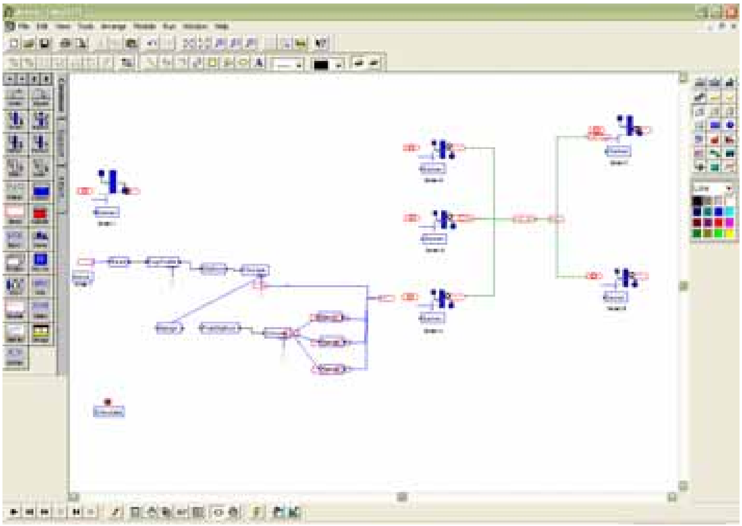

Figure 3. The modules used for constructing the dispatching model

6 VERIFICATION AND VALIDATION OF THE MODEL

After construction of the model, its correctness must be controlled. This task is performed using animation capability of the Arena modeling system. Verification method will be done by entering one truck for each shovel and tracing the route of trucks during performance of the model. Selection of different color for each truck shall cause an easy tracing.

After making sure that the constructed model is right, the model is run. Then the results obtained from the execution of the model are compared with the current situation in the mine to validate the model. If the results are same and the model is valid, various scenarios are set under which, the model will be run for optimization.

7 COMPARISION THE RESULT OF DISPATCHING AND NON-DISPATCHING METHOD

In Fig. 4, the results of optimization were obtained from Fuzzy Goal Programming, Arena Simulator model and real production of mine, were shown. Real production of mine is as a result of no-dispatching method usage. As it is obvious, production rate has been increased by using both two mentioned optimizing methods.

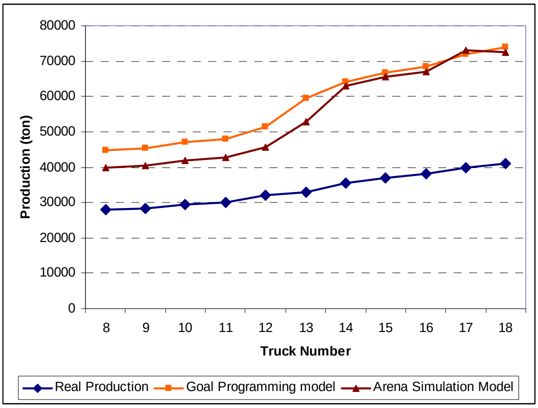

Figure 4. Comparision the result of dispatching and non-dispatching method

8 CONCLUSIONS

Simulation is powerful tool for analysis of performance of most mining systems. Using this technique, most complicated problems can be solved with fewer simplifications.

The Songun mine is able to reach its scheduled production target by employing 14 trucks each of 136 ton capacity. With the current situation, without transfer of a major part of its planned production to the private sector.

Application of dispatching model can be effective in reduction of the number of trucks for achievement of a specific production level. The model introduced in this paper together with the technique adapted, can serve as a useful tools in all types of open cast mines. It was shown the substantial saving can be achieved by using these methods.

9 REFERENCES

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