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Research Paper

Developing a Local Search Algorithm for Solving the Allocation and Dispatching Problem of Transportation Fleet in Open Pit Mines

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Abstract: Loading and haulage operation in open pit mines is the last stage of the mining process. truck- shovel system, due to its many advantages including high flexibility, is preferred for this operation. Due to high operating costs, proper fleet management and optimization can significantly affect the project economics. Truck allocation and dispatching issue is a very complex problem, especially in large mines with numerous loading and dumping points. Because of the problem size and complexity, employing mathematical methods is not justified due to very high solution time which leads to employing super computers. To overcome the aforesaid shortcoming, heuristic algorithms can be applied. In this paper, in MATLAB environment, a heuristic algorithm was developed to solve allocation and dispatching problem of transportation fleet of a real mine. According to the obtained results, a running time of 39 seconds was computed for the heuristic algorithm. Finally, the same problem was solved with an available mathematical model with a running time of 24 hours which shows the superiority of the proposed algorithm over the mathematical modeling.

Keywords: Loading and haulage operation, Allocation and dispatching problem, Heuristic algorithm.

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INTRODUCTION

The truck-shovel system is one of the most widely used systems in open pit mines [1]. Truck allocation and dispatching, especially in large mines with a large number of loading and unloading points, is a highly complex problem. In addition to meeting the production goals, suitable fleet management reduces overall costs, also [2]. Truck fleet management is done by two methods of fixed and flexible allocation [3]. In fixed assignment, each truck is assigned to a shovel at the beginning of the shift, whereas, in flexible allocation, each truck can be assigned to different loading and unloading points [4]. In this type of problems, for each of the loading points, the order of the sequence of trucks and the start and end times of each sequence are determined separately [5]. In the problem of designing transportation systems, maximum effort is to optimize the allocation and dispatching with minimum idle times which in turn leads to minimization of the total costs [6]. It is worthy to mention that mathematical modeling is usually used to solve fixed allocation, on the other hand for dispatching problems, simulation method is applied [7,8].

Mathematical modeling has been used by various researchers for truck allocation [1-8]. In mathematical modeling, the problem is solved with various techniques, i.e., linear programming, integer programming, dynamic programming, goal programming, and stochastic programming. It can be said that in the past, the allocation and dispatching were considered separately; however, simultaneous solving can cause better results [5]. Despite the above-mentioned advantage, if the size of the problem is large, the solution time becomes very high and therefore ordinary computers may not be applicable [9]. To cope with this circumstance, heuristic methods can be used as an effective alternative for diminishing solution time [9,10]. The purpose of this study is to develop a heuristic algorithm for solving the problem of allocation and dispatching of transportation fleet in open-pit mines. Finally, the verification of the proposed algorithm is accomplished by a recently developed mathematical model.

METHODS

To solve the allocation and dispatching problem, a heuristic algorithm was developed in MATLAB environment. One of the main goals in open-pit mine transportation systems is to minimize the completion time of the entire operation. This can be achieved by reducing the length of the queue and thus the waiting time of trucks and by optimizing the dispatching schedule and thus reducing the idle time of shovels.

The inputs of the proposed algorithm include the volume of mined blocks, the capacity of the trucks and the times of loading, transporting, dumping and visiting the next loading point. It should be noted that the start and end of truck work is considered parking. Alternatively, the outputs include allocation and dispatching plan. In the developed algorithm, the following criteria have been applied for allocating trucks:

1) Assignment based on the shovel remaining time for commencement of loading
2) Assignment based on the shovel required production (job) capacity
3) Assignment based on the shovel engagement situation
4) Assignment based on the shovel loading time
5) Assignment based on the trucks queue length
6) Assignment based on the shovel job completion

Solution steps of the algorithm are as follows:

Step 1: Algorithm inputs are prepared in the form of a matrix.

Step 2: Based on the defined truck allocation criteria, one shovel is selected.

Step 3: A truck is assigned to the primarily selected shovel. If the shovel is occupied in loading another truck, the dispatched truck will have to wait in the queue. The truck waiting time is recorded.

Step 4: If the shovel is ready to load but no truck is available, the shovel waiting time (idle) is recorded.

Step 5: After each truck is unloaded, the remaining job is checked for completion; if it is finished, then the truck will be moved to the parking lot.

Step 6: Steps 2 to 5 are repeated until the stopping condition is met and the operation total time is recorded.

Step 7: Steps 2 to 6 are performed for different truck sequences to find out the optimum alternative.

FINDINGS AND ARGUMENT

To investigate the performance of the developed algorithm, an attempt has been made to solve a real problem related to an open pit mine. In the defined problem, there are 4 shovels, each of which must load a block of 900 tons. Also, there are 18 trucks with a capacity of 100 tons. The relevant input parameters are given in Table 1.

Table 1. Input data

Operations	Time (min.)
Starting	04.00
Loading	03.25
Hauling	13.00
Dumping	02.00
Returning	07.00
Parking	07.00

For the developed algorithm, completion time of 67.50 min was reached with a running time of 39 seconds. On the other hand, for the mathematical modeling, completion time was calculated 70.75 min with a gap of 23% and with 24 hours running time. As it is seen, by using the developed algorithm, the solution time was significantly reduced. It is noted that with considering lower gaps, the running time would be much higher.

According to the Figure 1, the idle time of each shovel from the operation commencement to the end of operation is calculated 12.25 min. In other words, out of 166 minutes of the total possible operational time, the shovels efficacy is computed 70%, which is satisfactory as compared to the mathematical model. Also, the waiting time of trucks was calculated 22.75 min. In this way, out of 1107.75 minutes of the total possible operational time for trucks, the efficacy was calculated 98%. In the same way, using mathematical modeling, the efficacy of trucks was computed 92% (Table 2.)

Table 2. Scheduling the sequence order of trucks and their waiting times (min.)

Truck ID	First order starting time		First order finishing time		Second order starting time		Second order finishing time		Waiting time	
	TSSA	CPLEX	TSSA	CPLEX	TSSA	CPLEX	TSSA	CPLEX	TSSA	CPLEX
1	04.00	04.00	29.25	29.25	29.25	29.25	54.50	54.50	00.00	00.00
2	04.00	07.25	29.25	32.50	29.25	45.50	54.50	70.75	00.00	13.00
3	17.00	04.00	42.25	29.25	42.25	42.25	67.50	67.50	00.00	13.00
4	13.75	07.25	39.00	32.50	42.25	35.75	67.50	61.00	03.25	03.25
5	10.50	07.25	35.75	32.50	35.75	35.75	61.00	61.00	00.00	03.25
6	07.25	10.50	32.50	35.75	32.50	35.75	57.75	61.00	00.00	00.00
7	13.75	10.50	39.00	35.75	39.00	42.25	64.25	67.50	00.00	06.50
8	04.00	10.50	29.25	35.75	32.50	35.75	57.75	61.00	03.25	00.00
9	07.25	13.75	32.50	39.00	32.50	39.00	57.75	64.25	00.00	00.00
10	07.25	13.75	32.50	39.00	35.75	39.00	61.00	64.25	03.25	00.00
11	10.50	17.00	35.75	42.25	39.00	42.25	64.25	67.50	03.25	00.00
12	07.25	07.25	32.50	32.50	35.75	45.50	61.00	70.75	03.25	13.00
13	10.50	13.75	35.75	39.00	35.75	45.50	61.00	70.75	00.00	06.50
14	10.50	13.75	35.75	39.00	39.00	42.25	64.25	67.50	03.25	03.25
15	13.75	17.00	39.00	42.25	39.00	45.50	64.25	70.75	00.00	03.25
16	17.00	04.00	42.25	29.25	42.25	39.00	67.50	64.25	00.00	09.75
17	13.75	04.00	39.00	29.25	42.25	32.50	67.50	57.75	03.25	03.25
18	04.00	10.50	29.25	35.75	29.25	39.00	54.50	64.25	00.00	03.25

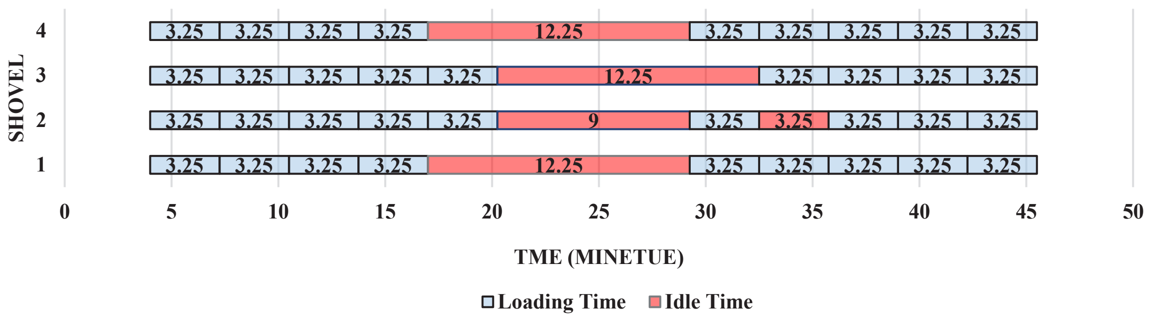

Figure 1. Truck loading schedule and shovel idle time

CONCLUSIONS

In this study, an attempt had been made to solve the problem of truck allocation and dispatching in open pit mines. Since this type of the problems are normally big in size, mathematical methods may not be applicable, because the solution time is so high that utilization of super computers is inevitable. In this research, to cope with this challenging point, a novel heuristic algorithm was developed to reach the near optimum solution in the minimum possible time. For developing the algorithm, different criteria were defined for truck assignment. According to the obtained results, the solution time with the developed algorithm was 39 sec., which is appreciable with that of mathematical model (i.e., 24 hours).

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