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Performance Analysis of Mehdi Abad Lead & Zinc Mine Haulage System with Discrete Event Simulation

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Abstract

In this research, the current performance of loading and haulage operations for waste transportation in Mehdi Abad lead and zinc mine is modelled and analyzed using Arena software based on discrete event simulation technique . Then some appropriate improvement approaches are suggested. First, trucks and loaders are identified as simulation entities and resources by analyzing production operations. Then, mine pit, repair shops, and waste dump are defined as model subsystems. After analyzing the collected data of loading, haulage, and navigating times of mine roads, the distribution functions of each operation are estimated with the Input Analyzer tool. According to the simulation results, the loader productivity of the mine is low, which will increase as the depth increases. So that it requires two 30-ton trucks to fill the effects of 300 meters haulage road expansion. Then, the behavior of the system is simulated with two scenarios defined including decreasing overloaded loaders and adding trucks in 105 different modes. According to the results, doubling the number of 30-ton trucks will maximize both the average service of loaders and trucks. On the other hand, it is possible to remove 2 to 3 loaders without significantly altering the performance of the remaining active loaders.

Keywords

Mine fleet management, Mehdi Abad Lead &Zinc mine, Discrete Event Simulation, Arena software.

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1- Introduction

Loading and haulage operations are the most costly operating units in mining activities and there is a close relationship between improving fleet performance and increasing profitability or mining efficiency. The research that has been done to improve fleet productivity can be classified into three categories: mathematical optimization models, simulations, or a combination of simulation and optimization. Mathematical optimization techniques are mainly based on the use of operation research models to optimize the defined objective functions by considering the constraints of each model, but the simulation of a system is based on the desired characteristics. It is a simple and inexpensive way to observe the performance of systems in real or altered conditions. Due to the loading and haulage activity at discrete time intervals, in this research, discrete event simulation is used. In this method, a system is modelled by defining specific goals and boundaries, and its activity is defined in the form of some discrete and consecutive events with probable times at a moment or time intervals. By running the model at different time intervals, the system performance is simulated with its response to various actions.

, Mehdi Abad lead and zinc mine was selected for this research, which is located 115 km south of Yazd city in Iran, with two operations of development and overburden stripping overburden currently considered as the main activities. According to the latest estimates, the mine geological reserves of lead and zinc are 716 million tons, and the mineable reserves are about 154 million tons. The loading and transportation system of the mine, which is currently in the stripping phase, includes 11 loaders, excavators, and shovels, as well as 34 trucks with capacities of 30 and 100 tons. According to the design, the final pit of the mine, with 1903 meters of length and 1433 meters of width, will expand to a depth of 340 meters.

The main purpose of this study is to simulate the current state of loading and haulage systems of Mehdi Abad lead and zinc mine, and to improve the fleet performance. Also, the fleet behaviour will be analyzed with changing transportation distances, eliminating low-performance loaders and adding trucks to the transport system.

2- Methods

The general haulage system of the mine includes three subsystems of the mine pit, a repair shop (with parking), and discharge dumpers. Trucks are considered entities and loaders are considered as resources. To build the model, the following data are required:

- Capacity of machines
- The probabilistic istribution function of entities activity time
- The mean time to repair (MTTR) and mean time to failure (MTTF) for resources (loading fleet)

In order to simulate the transportation system, route travel times by entities (trucks) were collected along with the loading operations times (by sources) according to the type of device. The collected data of mining machinery includes over 3000 records in a few specific days of the year and the minimum number of data used to estimate the distribution function of each sub-activity is 40 sets of data. After collecting the data and plotting their histogram, the best possible time distribution for each of the sub-activities is selected based on the least error. Time distribution functions including loading, unloading, and traversing times of mine routes and their delays are estimated with the Input Analyzer tool in Arena software, and the results are shown in Table 1. The cross sign in Table 2 means that the capacity of the truck does not fit the loader, and in system modeling, the truck is not serviced by the loader, and the truck is not placed in line with the loader.

Table 1: Distribution Function of Model Probabilistic parameters

Probabilistic Distribution Function(sec)		Activity type	
HD 785	**HD325**		
54 + ERLA (36.3, 2)	×	Shovel	Loading Time
TRIA(203, 244, 618)	NORM(174, 24.7)	EX850	
219 + EXPO(104)	NORM(174, 24.7)	EX800	
NORM(167, 37.8)	36 + LOGN(60.7, 251)	LD800	
×	NORM(158, 55.4)	LD600/470	
2.5 + ERLA(3.39, 5)		Truck Maneuver and Placement	Delay and Maneuver Time
NORM(30, 5)		Shift Switching(Min)	
24.5 + ERLA(11, 4)		Dumping Time of Trucks	
55 + WEIB(321, 3.3)		From Parking to Pit	Fixed Times
105 + WEIB(321, 3.3)		From Pit to Waste Dump	
95 + WEIB(321, 3.3)		From Waste Dump to Pit	
65 + WEIB(321, 3.3)		From Waste Dump to Parking	
TRIA(30, 40, 60)		From Parking to Repair Shop	
TRIA(27, 36, 54)		From Repair Shop to Parking	

Table 2:Truck Performance Analysis based on Iteration Number of Model

Average Performance of Trucks		KOM 325		KOM 785		Number of Iteration
Changes Percentage	**Services number**	**Changes Percentage**	**Services number**	**Changes Percentage**	**Services number**	
	40.32		677		694	1
-5.47%	38.12	-12.11%	595	1.01%	701	3
11.81%	42.62	11.93%	666	11.70%	783	8
13.25%	48.26	23.27%	821	4.73%	820	12
-5.12%	45.79	-3.05%	796	-7.20%	761	17
7.96%	49.44	-2.26%	778	18.66%	903	20
-13.50%	42.76	-17.61%	641	-9.97%	813	25
-4.26%	**40.94**	**-13.88%**	**552**	**3.32%**	**840**	**30**

Mehdi Abad mine was simulated in three 8-hour shifts, each simulation was performed in 25 hours (1500 minutes) to provide sufficient time for performing semi-finished services and incomplete cycles in the model. To ensure stable results, the model was run for a different number of repetitions. Based on the value of changes in output parameters, after 30 iterations, the model institutions has the least changes in performance and thus appropriate stability after 30 iterations, so the number was considered as the limit of model repetition. Table 2 shows the output values for number of services and operating tonnage of each truck type in three 8-hour shifts with different iterations.

To validate the model, the number of services and tonnage transported by trucks as transport system entities (including loading, transportation, and unloading) was considered in 3 shifts as the main indicator of model validation with real performance data. The transportation system was compared. The average simulation error is 6.86% according to the tonnage criterion, based on the performance index of entities, and 9.87% based on the performance of resources.

3- Findings and Argument

Analysis of the model outputs for each device shows that the loading entities are continuously operating except in cases of failure. However, based on Fig.1, low capacity loaders give poor performance of devices, while higher capacity loaders have acceptable numbers of services. Also, the mine is faced with an increase in number of loaders or a lack of carriers due to the inappropriate number of trucks and loaders. On the other hand, according to Fig. 2, between 15 and 22 cases of official failure occur in one day, most of which are short-term. The important point is the service limitation of the repair shop, which causes a queue at the entrance of the unit, and dcreases the number of active and ready-to-serve entities over time. This can be interpreted by reducing the slope of the service performance curve for trucks and loaders in the third shift (simulation hours 16 to 24) compared to the first shift. It is recommended to keep the repair shop unit open for more hours in order to provide faster service.

Then two scenarios were simulated, and implemented in the analyzed model; increasing the carrying distance and ultimately increasing the depth of the mine pit or expanding the range of tailings dump, and also reducing the carrying distance due to new ramps or activating the processing plant at a shorter distance. Accordingly, increasing the distance by up to 10% has little effect on the performance indicators of the loading and carrying fleet (Table 3). Therefore, according to the current conditions of the mine, two types of strategies are suggested to improve the productivity of existing loaders in the mine; reducing the number of active loaders in the mine, and increasing the number of carriers.

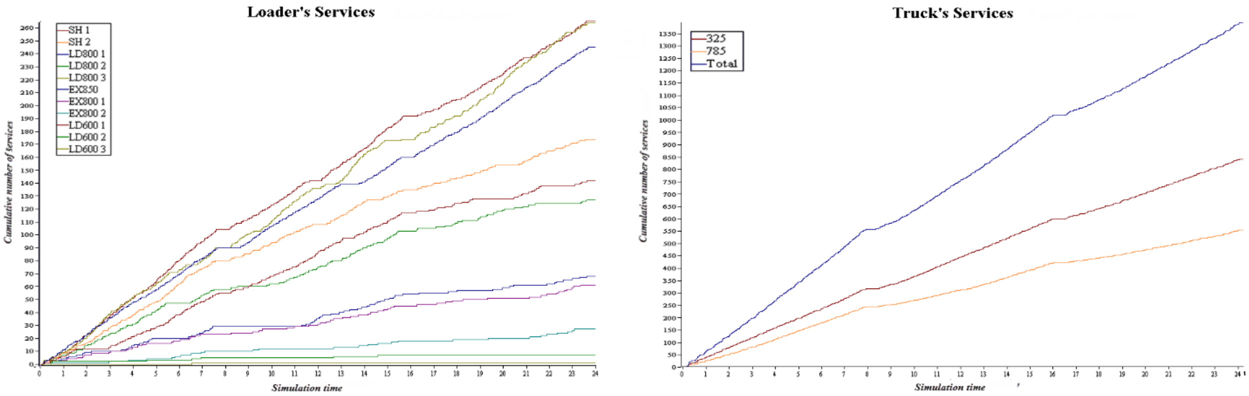

Fig.1: Simulation model output for the cumulative number of services by types of loaders and trucks

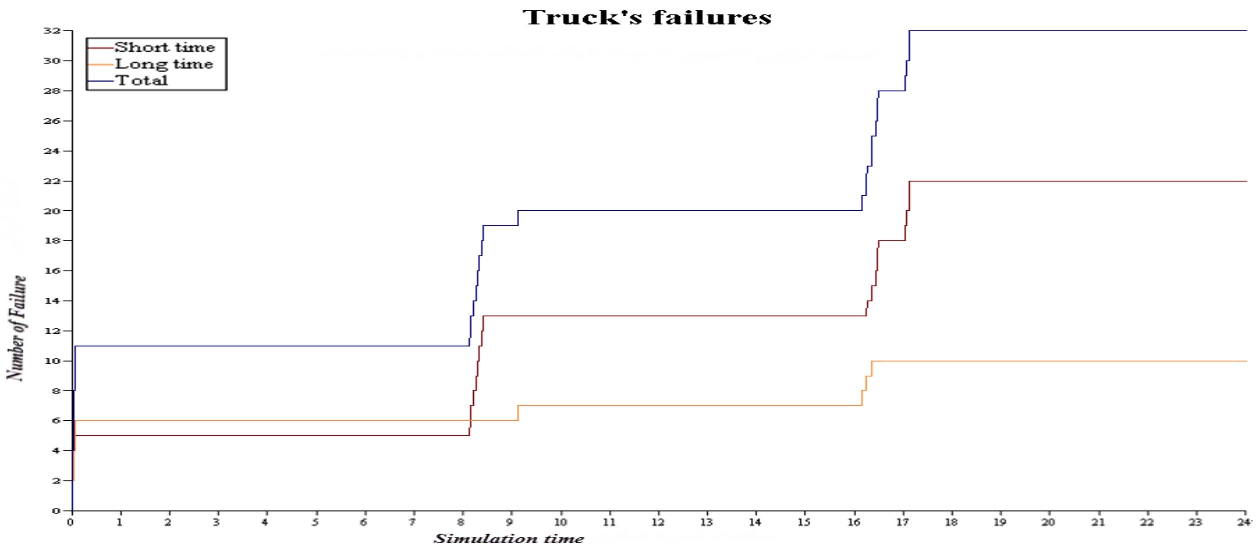

Figure 2: Simulation of the number of machine failures (short-term and long-term)

The results of implementing 11 different scenarios in 24 hours of model operation are shown in Fig.3 based on the average tonnage performance of each loader and truck. Accordingly, considering the type of loaders, the removal of 1 or 2 loaders has a small effect on fleet performance, but with the elimination of the two loaders Ld600 and EX800, performance of the remaining active loaders approaches its operational capacity. Therefore, the removal of loaders is suggested as the best scenario.

Table 3: Simulated effect of Haulage distanceon fleet efficiency

Mean efficiency		Daily Truck Services		Distance Change
Trucks	Loaders	Model785	Model 325	
2180	6737	585	619	20%
2124	6565	571	709	15%
2211	6833	562	741	10%
2148	6640	525	795	5%
2263	6995	552	840	(0%) Base
2548	7875	687	712	-5%
2760	8529	744	771	-10%
2698	8338	660	993	-15%
2649	8187	657	947	-20%

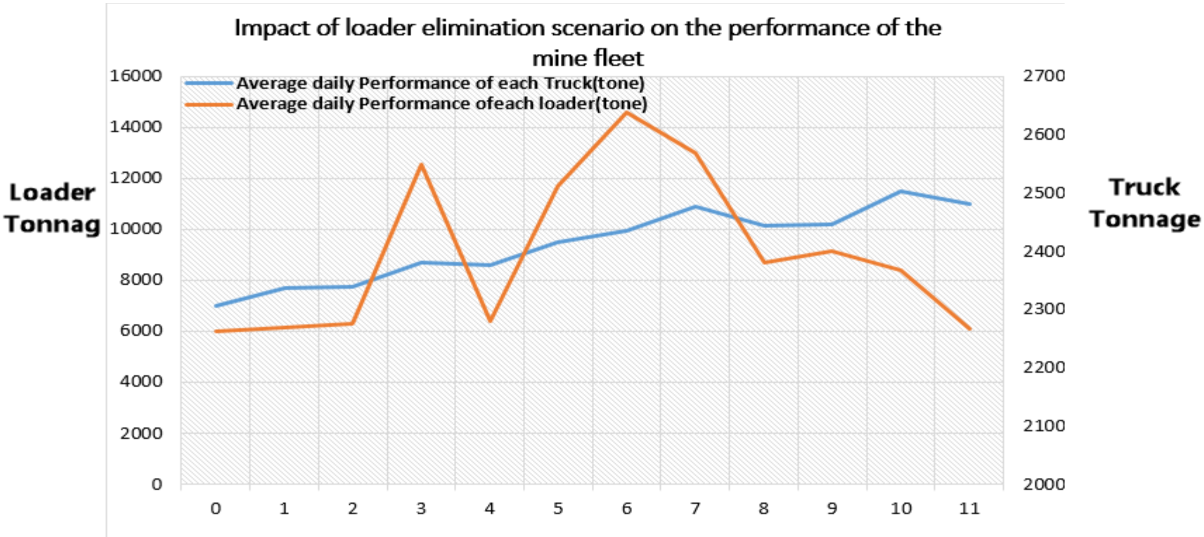

Fig 3: Comparison of changes in average daily tonnage of loader and truck for each of the scenarios

Then, according to the activity of 30 and 100-ton trucks, and the difference in the effect of their numbers on the fleet performance, 52 different scenarios were defined:

- Double the number of 30 ton trucks (scenarios 1 to 18)
- Almost double the number of 100 ton trucks (scenarios 19 to 32)
- Increase the number of trucks as a combination of 30 ton and 100 ton trucks (scenarios 33 to 52)

After implementing the scenarios in the model, the output values are compared. According to Fig.4, the 31st scenario is proposed as the best approach to increase the number of trucks based on the criteria for maximizing the efficiency of the shipping fleet. Also, addition of 30-ton trucks has a greater impact on increasing the efficiency of excavator services and Ld600 loaders, but there are no significant changes in the performance of Ex800 shovels and loaders. Increasing the number of 100-ton trucks practically increases the number of service excavators and Ld600 loaders, which are highly functional in current situation, and increases the waiting time for trucks to be loaded from these loaders.

It should be noted that in the current situation, with an increase in the number of carriers, the repair shop unit will not be needed, so upgrading the capacity of the repair shop unit works as an auxiliary solution to increase the number of active carriers repaired.

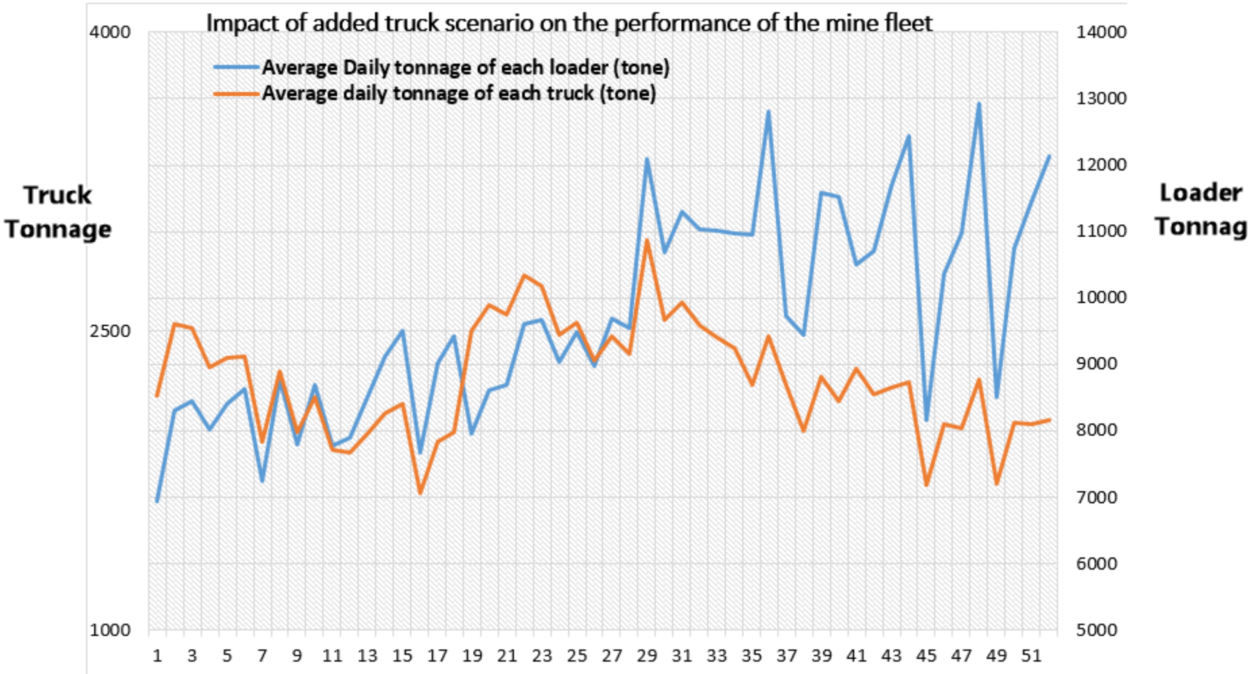

Fig 4: Comparison of changes in average daily tonnage of loader and truck for each of the scenarios on increasing the number of trucks

4- Conclusions

In this paper, an attempt was made to model the operation of loading and transporting in Mehdi Abad lead and zinc mine by implementing a discrete incident technique. After validation and analysis of the current condition of the mine fleet, it was found that the mine is facing a decrease in the productivity of loaders and unemployment of some, which would increase with the depth of the mine and the length of transportation routes. Then, the behavior of the system in case of changing haulage distances, changing the number of entities (trucks) and resources (loaders) in the form of different scenarios was analyzed.

Based on the results, in the current situation, it is possible to remove 2 loaders from the fleet without making a significant change in the performance of the remaining loaders, subject to the removal of low-performance loaders and assuming technical feasibility and disregard for considerations of the number of active work faces. Also, if the current situation is suitable and the mine is not developed, the scenario of removing loaders without the need for new investment with high flexibility can be appropriate in improving the performance of the system. In terms of increasing the number of trucks, investment is proposed to increase the number of 30-ton trucks, which maximizes both the average tonnage criteria of loaders and carriers. It should be noted that the proposed scenario is based solely on maximizing the performance of the shipping fleet, and cost-benefit analysis is necessary to make the final decision on fleet size expansion.