Research Inventy: International Journal of Engineering And Science
Issn (e): 2278-4721, Issn (p):2319-6483, PP: 38-42
www.researchinventy.com

Optimization of Truck Dispatch System in Opencast Mines by using Machine Learning Algorithm Models

Satyam Choudhury [1,] Dr. Hrushikesh Naik [2,]
[1]*Dept. of Mining Engineering, NIT Rourkela-769008*
E-Mail: satyam.nitrkl@gmail.com
[2]*Dept. of Mining Engineering, NIT Rourkela-769008*
E-Mail: hknaik@nitrkl.ac.in
⁎Corresponding author's e-mail address is hknaik@nitrkl.ac.in

Abstract
Nowadays with advancements in science and technology, high mechanization is possible in surface mining methods. To increase their production many mining industries are using various types of heavy earth moving machineries such as high-capacity dumpers, shovels, draglines, etc. In these surface mining operations, the dumper haulage system contributes the most in total operating cost of any mine. It is estimated that an average mining company spends around 50% to 60% in this truck haulage system only. So utmost care must be taken to keep up an effective haulage framework. Therefore, to reduce the cost of operation the dumpers must be allocated and dispatched efficiently. Therefore, in this paper to enhance the productivity of truck haulage system an attempt is made to minimize the cycle time of dumpers and allocate an optimized number of dumpers to one shovel so that the idle time of dumpers can be minimized. In determining the cycle time of dumpers predicting the traveling time in different situations is given utmost importance. For this machine learning models are used which helped us in predicting the traveling time in the different atmospheric situations of the mine. This approach of integrating the machine learning methods in minimizing the cycle time will provide a proper estimation of performance measures, truck scheduling, and finally an optimized truck dispatch system.
Keywords: *Opencast mine, Truck dispatch system, Dumpers, Shovels, cycle time, scheduling, Overall equipment effectiveness, machine learning, Optimization*

I. Introduction

The Open pit mining methods are using extremely expensive machinery such as dumpers, shovels, and loaders of high capacity to increase their production. Therefore, there is a need of optimization of the utilization of such machines and at the same time operational cost should be reduced. This can be done by developing a sophisticated dumper haulage system which ultimately ensure an efficient utilization of equipment. In this paper the truck assignment approach has been implemented which uses the machine learning algorithm method. A general estimation shows that the surface mine alone contributes 70%-80% of total production of minerals in India. The open cast mining operation consists of loading of minerals at face, hauling and dumping operations. Shovel-Dumper systems being the most flexible and efficient are mostly used in almost all surface mining activities. The mining industries always give importance to productivity and profitability. So, there is a need of automation in these systems. The three important components of material handling in any surface mine are dumper, excavator, and loaders. The dumper hauls the materials from loading station to desired unloading station. One hauling cycle may consist of some productive work as well as non-productive works. Productive work of dumper includes total travelling time of dumper, spotting time, loading/unloading time etc. Whereas idle time, breakdown time may be included in the unproductive time. In this work we have tried an approach which is developed to reduce the non-productive time to increase utilization of available machinery. The total travelling time of the dumper being loaded or empty take most of the portion of total cycle time. So, to minimize the hauling cycle time it is very crucial to predict the travelling time of dumper at different situations. This travelling time generally depends on the atmospheric conditions such as wind speed, dustiness of the atmosphere, precipitation, temperature etc. The dumper condition, driver experience and some other aspects also affect the travelling time but, in this work, the atmospheric conditions are only used to predict the traveling time using machine learning models. This predicted travelling time further integrated with linear/integer programming methods for overall optimization of the truck scheduling system. Now-a-days with the development of GPS system many of the open pit mines are using the automated truck dispatch system (TDS) and fleet management system (FMS). In these systems real field data like truck location, its travelling time, total working hour etc. can be collected. The data can be used to train the machine learning model such that it predicts the traveling time with less error. In this work attempts are made to:

- Develop the machine learning model to predict total travelling time of dumper in different situations
- Develop an objective function for total cycle time of dumper
- Develop linear/integer programming method using Machine learning technique to minimize the total cycle time.
- Optimize the dumper scheduling assignment

Truck Scheduling System:

The main objective of the truck scheduling systems is to improve the OEE while reducing the operational cost at the same time over a particular time (e.g., one shift). To achieve this aim objective functions with different constraints are developed to find truck schedule that uses the optimized number of trucks. An objective function to minimize the total cycle time is also constructed so that one can get maximum equipment utility. These objectives are suitable to the mining conditions as the shovels and loaders are expensive equipment. In this approach we have considered the following:

- Dumpers from different shovels can travel on and dump the material at same dumping site.
- Truck of certain capacity cannot travel between the face and dumping site due to various constraints so in this problem we have considered same size for all the trucks.
- Driver experience and condition of truck are not considered while developing the prediction model.

To solve the truck scheduling/assignment problem we must first develop an objective function which can be optimized according to various constraints. Let us consider total number of shovels available in the mine is S, total number of dumping site is D and maximum fleet size of the mine is F. The goals are considered while developing the objective function.

- Minimization of number of trucks so that the utilization of shovels is maximum i.e., above certain threshold limit.
- Minimization of cycle time of the dumpers.

Assuming x (s, d, f) be the number of dumpers travelling from between shovel to dumper and vice versa the optimization problem can be mathematically expressed as:

$$\text{Minimize } Z = \sum_{d=1}^{D} \sum_{s=1}^{S} \sum_{f=1}^{F} x(s,d,f)$$

Subject to $U(S) >= C_{S,}$ s = 1, 2..., s

$$\sum_{d=1}^{D} \sum_{s=1}^{S} x(s,d,f) \leq N(f)$$

$$\forall(s,d,f)\ x(s,d,f) \geq 0$$

$$\forall(s,d,f) \in R\ x(s,d,f) = 0$$

Here U(S) = utilization of shovel s

C_S = Desired utilization of shovel for maximum productivity

$N(f)$ = Total number of trucks

R is a particular set of nonviable triplets (s, d, f) which signify constraints such as shovel matching problem, road constraints etc.

The utilization of shovel over the total cycle time can be defined as:

$$U(S) = 1 - \frac{Wt(S)}{T} \quad s = 1,2\ldots., S$$

Where Wt(s) is total waiting time of shovel during the period T. This shovel waiting time can be estimated according to the total cycle time of each fleet/dumper. Waiting time of shovels is developed as:

$$Wt(S) = T - \sum_{d=1}^{D} \sum_{f=1}^{F} \frac{T.x(s,d,f)}{Tcycle(s,d,f)} T_{loading}(s,f)$$

The cycle time of the dumper consists of empty travel of the dumper, spotting of the dumper, loading, hauling the material to the dump site and dumping as the productive work. There are also some unproductive activities like idle time, breakdown time and maintenance time of dumper. Thus, the actual cycle time of a dumper is estimated as:

$$T_{cycle}(s,d,f) = T_{empty}(s,d,f) + T_{spoting}(s,d,f) + T_{loading}(s,d,f) + T_{haul}(s,d,f) + T_{unloading}(s,d,f)$$

So, by combining the above two equations the constraint equation for utilization factor can be determined and used while solving the optimization problem.

The objective of minimizing total number of trucks at the loading point, number of trucks travelling on the road and number of trucks at dumping site can also be written as follows:
Minimize Z = (Number of trucks travelling on the road × Travelling time of the truck in that path) + (Number of trucks at shovel × (loading time + spotting time)) + (Number of trucks at dump) × (unloading time + spotting time))

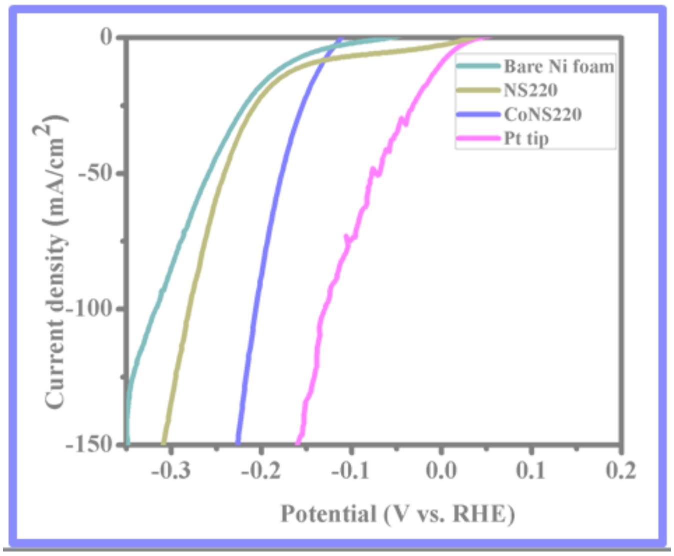
This can also be written as:

$$\text{Min } Z = \sum_{d=1}^{D} \sum_{s=1}^{S} \sum_{f=1}^{F} x(s,d,f) \times (T_{haul}(s,d,f) + T_{empty}(s,d,f))$$
$$+ \sum_{s=1}^{S} x(s) \times (T_{spoting}(s) + T_{loading}(s))$$
$$+ \sum_{d=1}^{D} x(D) \times (T_{spoting}(d) + {}_{Tunloading}(d))$$

Subject to $U(S) >= C_{S,}$ s = 1, 2..., s

$$\sum_{d=1}^{D} \sum_{s=1}^{S} x(s,d,f) \leq N(f)$$
$$\forall (s,d,f)\ x(s,d,f) \geq 0$$
$$\forall (s,d,f) \in R\ x(s,d,f) = 0$$

Here $x(s,d,f)$ = Number of trucks travelling between the loading site to dump site
$x(s)$ = Number of trucks at the shovel/loading point
$x(D)$ = Number of trucks at the dump
T_{haul} = Time required to travel when the truck is loaded
T_{empty} = Time required to travel when the truck is empty
$T_{spoting}(s)$ = Spotting time of truck at shovel
$T_{loading}(s)$ = Time taken by shovel to load the truck
$T_{spoting}(d)$ = Spotting time of dumper at dump
${}_{Tunloading}(d)$ = Time required to unload the material at dump



Machine Learning (ML):

Over the last decades machine learning became a major part in the field of computer science and information technology. Gradually Machine learning is integrated with other fields such as mining engineering, civil engineering etc. as it can handle a large amount of data and process it at the same time. Machine Learning is an advanced version of computer science, which helps the computer to learn from its own feedback that does not need explicit programme. As shown in Figure 1 & 2 in machine learning it uses the data to learn their behaviour then it analyses these data to give the result. This whole process can be done with explicitly programming at every level.

Figure 1: Working process of Machine Learning

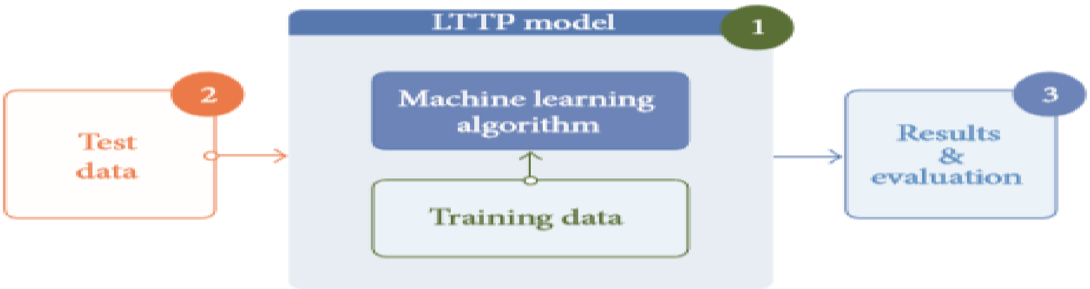


Figure 2: Experimental flowchart of Machine Learning method

Table 1: Preprocessed data for the training the prediction model

Data	**Value**
Truck ID	503
Truck type	BH – 60M
Truck status	Run
Load status	Yes
Starting Node	E
Arrival node	Dump
Wind speed(m/s)	1.5
Temperature((∘ C)	28
Relative humidity (%)	70
Precipitation (mm)	0
Rain	No
Travel time (hour: min: sec)	00:6:12

II. Results and discussion

Error calculation of ML model

To get the most suitable algorithm in accordance with the mining condition percentage error are calculated along with mean absolute deviation (MAD) and mean absolute percentage error (MAPE) given in Table 2 and 3.

Table 2. MAD & MAPE Value for SVM for the path F - D

Observed Travelling Time(sec)	Predicted Travelling Time	Absolute percentage error (%)
362	346	4.419889503
365	346	5.205479452
400	362	9.5
346	346	0
378	346	8.465608466
365	362	0.821917808
340	368	8.235294118
352	346	1.704545455
378	346	8.465608466
352	346	1.704545455
340	368	8.235294118
370	370	0
480	480	0
358	362	1.117318436
390	362	7.179487179
480	370	22.91666667
362	362	0
520	370	28.84615385
354	362	2.259887006
358	362	1.117318436

342	368	7.602339181
358	358	0

Table 3. MAD & MAPE Value for Knn

Observed Travelling Time(sec)	Predicted Travelling Time (sec)	APE (%)
362	346	4.419889503
365	346	5.205479452
400	362	9.5
346	346	0
378	346	8.465608466
365	362	0.821917808
340	368	8.235294118
352	346	1.704545455
378	346	8.465608466
352	346	1.704545455
340	368	8.235294118
370	370	0
480	480	0
358	362	1.117318436
390	362	7.179487179
480	370	22.91666667
362	362	0
520	370	28.84615385
354	362	2.259887006
358	362	1.117318436
342	368	7.602339181
358	358	0
340	362	6.470588235
365	362	0.821917808
365	362	0.821917808

III. Conclusion

Machine learning, Artificial Intelligence and various automation systems have a great potential in mining industry. It can reduce the operational cost and increase the productivity of the mine. Therefore, the mining system is slowly moving towards implementing these systems in various mines. In this paper an attempt is made to demonstrate an approach for the optimized truck scheduling system in a surface mine that uses the machine learning algorithm. This approach behaves stochastically in traveling time and queuing operation. The experimental results obtained in this study have shown the benefits of using machine learning in travelling time prediction which is ultimately used to optimize the truck allocation problem. This is achieved by using linear programming and different mining constraints. Finally, it is recommended that the application of machine learning along with operational research can make mines smarter and bring significant values to the mining industry.

References

[1]. A stochastic optimization approach to mine truck allocation, C.H. Ta, J.V. Kresta, J.F. Forbes, and H.J. Marquez (2005), International Journal of Surface Mining, Reclamation and Environment 19, 3, pp.162-175.

[2]. A practical simulation approach for an effective truck dispatching system of open pit mines using VBA, Y. Tan, and S. Takakuwa, (2016), in Proceedings of the 2016 Winter Simulation Conference, WSC2016, pp.2394–2405, IEEE, Washington, DC, USA, December 2016.

[3]. Forecast of applied effect for truck real-time dispatch system in open pit mine based on CSUSS, J. Li, R. Bai, J. Mao, and W. Li, (2010), in Proceedings of the 2010 International Conference on E-Product E-Service and E-Entertainment, ICEEE2010, pp. 1–4, IEEE, Henan, China, November 2010.

[4]. Road running time statistics method in truck scheduling, Q. Sun, (1998), Opencast Coal Mining Technology, Vol.01, pp.35–37,1998.

[5]. Real-time dynamic forecast of truck link travel time, R. Bai, J. Li, and J. Xu, (2005), Journal of Liaoning Technical University, Vol.1, pp. 12–14.