Simulation-Based Optimization of Truck Allocation in Material Handling Systems

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1 Introduction

Mining is an industry that needs costly equipment like excavators, loaders, etc. it costs several million dollars. A business must control its expenses. Transportation and also maintenance costs are two main costs. They form about 60 percent of operational costs, and a short improvement can save significantly.

Two approaches are suggested to reduce operational costs. Using trucks with more capacity to transport material to the dumpsite is the first option that brings some risks because we need to keep the utilization rate up. The second option is operation research techniques. The researchers were attracted by operations research techniques recently. The main goal of the articles was to improve productivity and efficiency and to determine the destination for trucks in the period.

This article seeks to explore a bi-objective mathematical model that aims to minimize the transportation costs and carbon produced simultaneously. Although this methodology is illustrated for surface mining operations, it also can be used for every kind of business that incorporates trucks and faces maintenance costs.

The contribution of this work is presenting a mathematical model that minimizes the transportation costs and carbon produced concurrently. The paper considers a limitation in the working hours for shovels and dumpsites. Also, different types of trucks with two age bins are considered in the developed mathematical model. The difference between the costs of using loaded and empty trucks is mentioned. It is the first study considering the impact of speed on transportation costs and carbon released to the environment.

Matin Ghasempour Anaraki, Masoud Rabbani, Moein Ghaffari and Ali Moradi Afrapoliand work on this article to achieve the object which are mentioned.

2 Modeling

sets, parameters and variables are as follows:

The objective function and constraints are as follows:

3 Result

the result of gams code is as follow:

as you can see, minimum cost of this question is 189144.

Sets	Description
p	Period
a	Age
t	Truck
s	Shovel
d	Dumpsite
Parameters	**Description**
C_t	Capacity of truck type t
CL_t	Cost of trucks type t when loaded per kilometer
CUL_t	Cost of trucks type t when unloaded per kilometer
AW_{sp}	Available waste at shovel s in period p
PR_{dp}	Production requirement of the dumpsite d in period p
SP_t	Speed of truck type t
AT_p	Available working time in period p
DC_{tap}	Discounted cost value for truck type t age bin a in period p
LSS_{ts}	Loading speed for truck type t in shovel s
LSD_{td}	Loading speed for truck type t in dumpsite d
F_{sd}	Distance from shovel s to dumpsite d
CP_{ta}	Amount of carbon produced by truck type t age bin a per hour
Variables	**description**
X_{tasdp}	Total trip numbers of trucks type t age a from shovel s to dumpsite d in period p
Y_{tasdp}	Total trip numbers of trucks type t age a from dumpsite d to shovel s in period p

Figure 1: sets, parameters and variables

4 sensitivity analysis

One of the things that can significantly reduce the cost is the capacity of the trucks. Now, we will draw the cost chart by changing the truck capacities.

as you see, when the capacity of truck type one reaches to 235, the cost starts to decrease, but as you can see, this decrease is fluctuating, for example, it increases a bit in the intervals like 240 to 242 or 245 to 246, but the main trend is decreasing.

as you see, when the capacity of truck type one reaches to 290, the cost starts to decrease, like type one, it has some fluctuations but the main trend is decreasing.

5 Conclusion

The equipment of material handling systems costs millions of dollars, so utilization at them can increase profitability. It can be gained by optimizing the schedule for equipment. Most articles related to mining operations are related to efficient production. Only a few were about the dispatching system. However, it is not an easy task according to conditions that confront different uncertainties. These variables impact unpredictable costs like unexpected equipment failures and operator effects. This paper presented a mathematical bi-objective model that aims to minimize truck transportation and maintenance costs. It also tries to minimize the carbon released to the environment because there are different types of trucks. They are of different ages, which makes a difference in the maintenance costs and pollution they cause. The presented model can save system costs by increasing equipment utilization and productivity especially in large-scale mines that include heavy equipment.

$$
\begin{aligned}
z = Minimize &\sum_{p=1}^{P}\sum_{a=1}^{A}\sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{d=1}^{D} CL_t \times X_{tasdp} \times F_{sd} \\
&+\sum_{p=1}^{P}\sum_{a=1}^{A}\sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{d=1}^{D} CUL_t \times Y_{tasdp} \times F_{sd} \\
&+\sum_{p=1}^{P}\sum_{a=1}^{A}\sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{d=1}^{D} DC_{tap} \times (X_{tasdp} + Y_{tasdp}) \times F_{sd}
\end{aligned} \tag{1}
$$

$$
z = Minimize \sum_{p=1}^{P}\sum_{a=1}^{A}\sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{d=1}^{D} CP_{ta} \times (X_{tasdp} + Y_{tasdp}) \times \frac{F_{sd}}{SP_t} \tag{2}
$$

Subject to:

$$
\sum_{t=1}^{T}\sum_{a=1}^{A}\sum_{d=1}^{D} C_t \times X_{tadsp} \le AW_{sp} \forall s \in \{1,\dots,S\}, \forall p \in \{1,\dots,P\} \tag{3}
$$

$$
\sum_{t=1}^{T}\sum_{a=1}^{A}\sum_{s=1}^{S} C_t \times X_{tadsp} \ge PR_{dp} \forall d \in \{1,\dots,D\}, \forall p \in \{1,\dots,P\} \tag{4}
$$

$$
\sum_{d=1}^{D} X_{tasdp} = \sum_{d=1}^{D} Y_{tasdp} \forall s = \{1,\dots,S\}, \forall p = \{1,\dots,P\}, \forall a = \{1,\dots,A\}, \forall t = \{1,\dots,T\} \tag{5}
$$

$$
\sum_{s=1}^{S} X_{tasdp} = \sum_{s=1}^{S} Y_{tasdp} \forall d = \{1,\dots,D\}, \forall p = \{1,\dots,P\}, \forall a = \{1,\dots,A\}, \forall t = \{1,\dots,T\} \tag{6}
$$

$$
\sum_{t=1}^{T}\sum_{a=1}^{A}\sum_{s=1}^{S}\sum_{d=1}^{D} X_{tasdp} \times \frac{C_t}{LSS_{ts}} \le AT_p \forall p \in \{1,\dots,P\} \tag{7}
$$

$$
\sum_{t=1}^{T}\sum_{a=1}^{A}\sum_{s=1}^{S}\sum_{d=1}^{D} Y_{tasdp} \times \frac{C_t}{LSD_{ts}} \le AT_p \forall p \in \{1,\dots,P\} \tag{8}
$$

$$
X_{tasdp}, Y_{tasdp} \ge 0 \tag{9}
$$

Figure 2: objective function and constraints

```
----      72 VARIABLE Z.L                      =    189144.000

----      72 VARIABLE X.L

INDEX 1 = t2  INDEX 2 = a2

               p1          p2

s1.d1       13.000      13.000
s1.d2       25.000
s1.d3                   25.000
s2.d1       12.000      12.000
s2.d2                   25.000
s2.d3       25.000


----      72 VARIABLE Y.L

INDEX 1 = t2  INDEX 2 = a2

               p1          p2

s1.d1       13.000
s1.d2                   25.000
s1.d3       25.000      13.000
s2.d1       12.000      25.000
s2.d2       25.000
s2.d3                   12.000
```

Figure 3: result of gams code

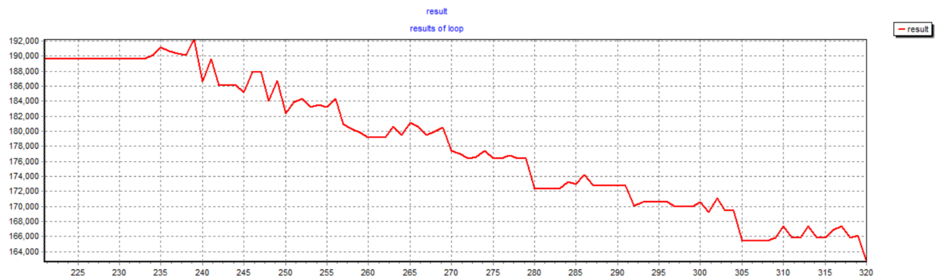

Figure 4: changing cost by capacity of truck type one

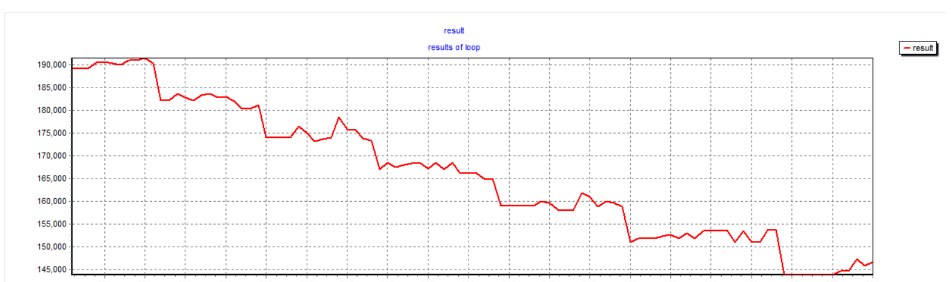

Figure 5: changing cost by capacity of truck type two