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Optimization of Shovel-Dumper Combination in an Open Cast Mine using Simulation Software

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Abstract: This is project is the combined usage of both mathematical and simulation techniques to address the issues of optimizations. This will be addressing only those factors which are commonly faced as a challenge during the management of fleet equipment system based upon a thorough literature study it has been found that many problems are associated with the combination of shovel-dumper system from equipment selection and their performance evaluating (matching factor, cycle time, allocation, queuing, loading time...) these are few Various methods have been employed to model truck-shovel system. Some of these methods rely on empirical rules or trial and error and some are highly mathematical requiring significant computational effort.
Keywords: Optimization, Shovel-Dumper Combination, Open Cast, Simulation Software, TALPAC

I. INTRODUCTION

Most of the world's solid minerals are mined in open-pit mines. The proportion of open- pit mining in recent decades has reached a high level (an average of about 75%), according to forecasts it will remain at this level for long period of time. A large proportion of open pit mining is explained by its advantages over underground mining such as higher labor productivity (10-11 times in coal mines), lower production costs (3- 4 times) and short terms of mine construction (2-3 times). The overall economic of surface mining is the removal of material in sub-surface, which involve the basic operation such as drilling and blasting, ore and waste loading, hauling, dumping and various auxiliary operations, while gaining maximum return on investment. Haulage in open-pit and strip mines is commonly accomplished by haul trucks, whereas the loading is accomplished by shovel, front end loader or hydraulic shovel. The role of haul trucks in many surface mines is restricted to cycling between loading zone (working face or shovel face) and unloading point (in-pit crushing station or conveyance system). The loading operation is done from mining face, where the loaders load the material onto the truck by many passes or cycle, the broken i.e. loaded ore is transported along the haul road. This process of transportation involves a careful planning and monitoring.

II. METHODOLOGY

The methodology of this project consists of literature studies, Collection of field data, Optimization of the cycle time using simulation software, Mixed Integer Linear Programming Model for allocation issues and Queue model.

A. The Literature Study

The literature study was done to identify the various issues associated with shovel and dumper combination

B. Collection of Field Data

Data on type of material, roaster, haul cycle, loading and transportation unit, operating cost, etc.

C. Optimization of the cycle time using simulation software
D. Mixed Integer Linear Programming Model is used to solve allocation issue.

The numbers and types of trucks and shovels are important parameters in optimal design of open-pit mine material-handling-and-haulage systems. Also, the numbers of trips from the mining face to the crusher, assuming that different sizes of trucks are operating in the mining face. Allocation problem involves determining the numbers and sizes of trucks and shovels, and how they will match up.

The cost of a shovel travelling from its location to a new mining-face location is also considered. Other assumptions considered in building the MILP model are as follows:

1) Each mining-face is available to be extracted at specific periods;
2) There is a maximum and minimum limit on the crusher's production capacity;
3) Specific types of trucks can work with specific types of shovels;
4) The number of available trucks of each type is known at the beginning of the period;
5) The number of available shovels is known at the beginning of the period;
6) Maximum and minimum production capacity of shovels and load capacity of trucks are known;
7) A truck's capacity, in terms of tonnes depends on the type of material it is hauling;
8) Only one shovel operates at each mining-face at a time;
9) Each shovel can operate at only one mining-face at a time;
10) The time horizon for the model is an eight-hour shift.

E. Queue Model

An appropriate Queue model formation necessitates some probabilistic characteristics and assumptions. The model is formulated with regard to truck arrival pattern, service discipline and service pattern, size of fleet equipment (shovel and truck), ultimate queue size and cost of idling.

III.INTRODUCTION TO TALPAC

Talpac is a software application designed to evaluate haulage fleet systems for the mining industry.. It is globally accepted as an industry standard for determining the productivity and economic of truck and loader hauling system using logic that models real haulage situations. Talpac allows the study of most factors affecting productivity and the sensitivity of productivity to these factors.

A. Talpac has the following Capabilities

1) Calculates fleet productivity for long-term and short-term planning by evaluating equipment, optimum loading techniques and bucket size.
2) Determines haulage costs using discounted cash flow analysis and incremental truck costing
3) Creates user- defines reports, including cost data and details about the haulage system

B. Input Data

The data used as input parameters in the simulation software are presented in the upcoming section. Table 1 and 2 elaborates the design specification and mine operating condition respectively.

Table-1

	Specifications	
Parameter	Truck	Shovel
Model	769 C	EX 800 H-5
Related Pay Load	25 t	3.3 Cu
GVW	67.586 t	
Quantity	7	

Table-2

Parameter	Mine Operating Conditions
Mine Type	Open Cast
Material Mine	Iron Ore
Cut-Off Grade	64%
Distance between loading & Dumping	2.1 Km
Point	
Gradients	1:10 (Bench to Bench) & 1:16 (Haul Road)
Optimal Speed of Empty Truck	25 km/h
Optimal Speed of Loaded Truck	15 km/h

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Considering the first input data shown , it exhibits the characteristic of the material being transported. The material being excavated is shale, due to its swell property, it has been considered as a loose volume. The bulk density and swell factor have been considered according to the shale property (Fig 1). The loader bucket loose density is calculated by Talpac using the formula from the below equation

$$\text{Loose Density}=\frac{\text{Insitu Bank Density}}{\text{Loader Bucket Swell Factor}}$$

For shale it is found to be 2.4 tonnes/cu.m. The fill factor is a measure of how a particular material fits into a bucket in comparison to the rated capacity of the bucket. As for our case the volume of the bucket is 3.3 cu.metre, the loader bucket fill factor was selected based on the experience of the shovel operator. It was considered to be good. The value of heaped and struck is set by the software as per the global fill factors scale for deferent loading unit.

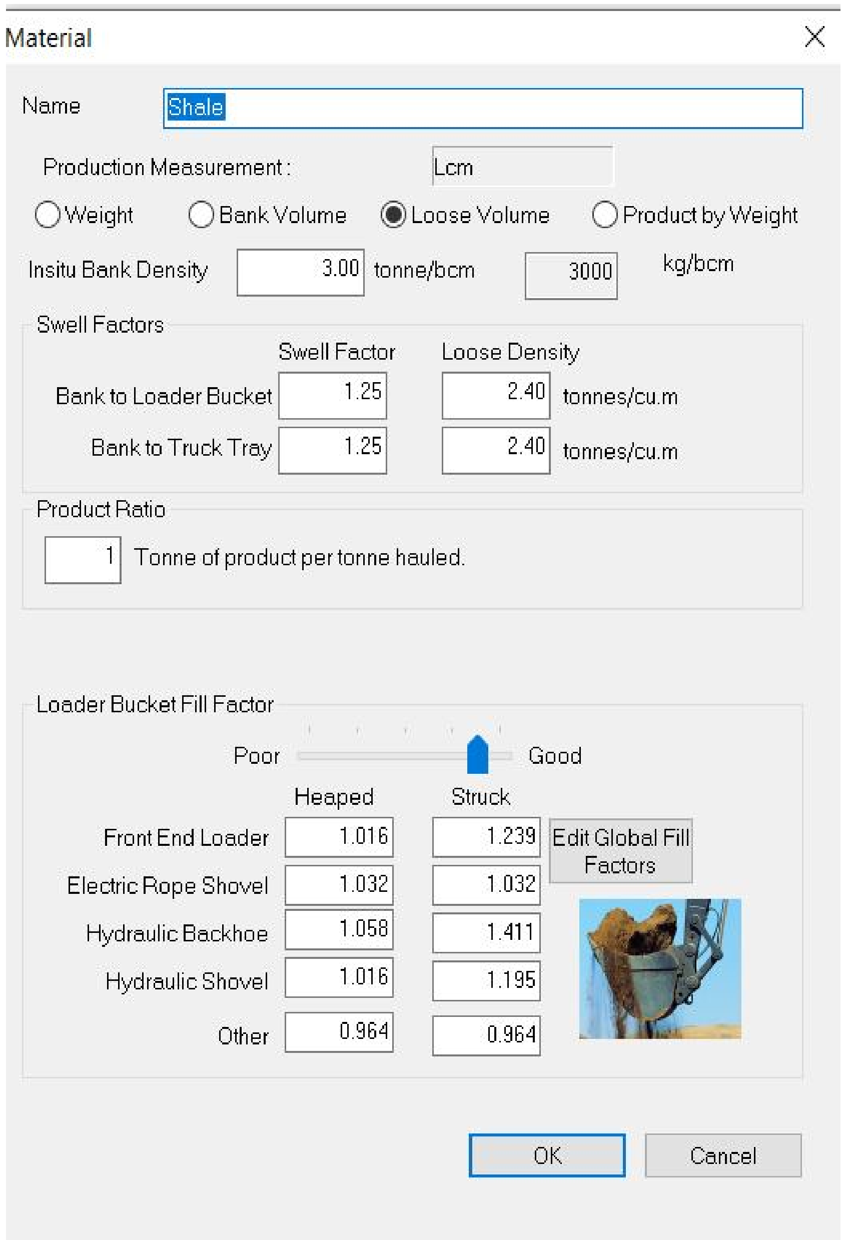

Fig-1 Characteristic of material (Talpac)

The roaster considered is 8hours shift duration, two shifts per day along with a general shift and six working days in a week. The next input parameter is the most important parameter, it gives the details about the haulage cycle. In our, the distance as mentioned in [table 2] is 2.1 km, it has been divided into several segments. Considering the grade percentage, the rolling resistance, the maximum and minimum velocity when full as well as empty . In the haulage segment, we found that Talpac create three (3) defaults segment by its own. And the more accurate is the haul road segment, more accurate the result. After inserting one-way trip one can reverse road way segments. In the haulage segment, the downhill part of the road has been allotted negative grade resistance (considered to be a grade assistance) and the zero grade resistance signifies that the ground is almost flat, which implies that from the loading point to the unloading point with an exception to the first segment (having a grade resistance of 10% meaning 1:10 as per the rules and regulations), which connect the loading bench to the second segment, most of the segment are downhill type. Offer a grade assistance to the truck plying on the road.

Edit Haul Cycle

Haul Cycle OK Cancel

Total Distance: 4404.0 metres (Forward = 2202.00 Reverse = 2202.00)
Total Elevation Change: 0.0 metres (Forward = -4.13 Reverse = 4.13)

	Type	Title	Distance metres	Grade %	Roll Res. %	Max km/h	Curve Angle	Final km/h	Load % of Full
1	Queue	Queue at Loader	Auto	Mins					
2	Spot	Spot Time at loader	Auto	Mins					
3	Load	Loading	Auto	Mins					
4	1	Spot to load	50.0	0.0	2.2	15.0	0.0	15	Empty
5	2	first Segment	300.0	10.0	3.0	15.0	20.0	15	Full
6	3	Second Segment	180.0	0.0	2.0	15.0	20.0	18	Full
7	4	Third Segment	200.0	-6.3	1.5	18.0	0.0	18	Full
8	5	Fourth Segment	200.0	-6.3	1.5	18.0	20.0	22	Full
9	6	Fifth Segment	300.0	0.0	1.5	22.0	0.0	20	Full
10	7	Sixth Segment	200.0	-6.3	1.5	20.0	20.0	20	Full
11	8	Seventh Segment	240.0	6.3	3.0	20.0	18.0	20	Full
12	9	Eigth Segment	150.0	0.0	2.0	20.0	0.0	20	Full
13	10	Nineth Segment	150.0	0.0	2.0	20.0	0.0	20	Full
14	11	Tenth Segment	182.0	-6.3	1.5	20.0	0.0	15	Full
15	12	Spottiing to dump	50.0	0.0	1.9	15.0	0.0	0	Full
16	Spot	Spot Time at Dump	Auto	Mins					
17	Dump	Dumping	Auto	Mins					
18	13	Spottiing to dump (rev.)	50.0	0.0	1.9	15.0	0.0	20	Empty
19	14	Tenth Segment (rev.)	182.0	6.3	2.0	20.0	0.0	20	Empty
20	15	Nineth Segment (rev.)	150.0	0.0	2.0	20.0	0.0	20	Empty
21	16	Eigth Segment (rev.)	150.0	0.0	2.0	20.0	0.0	20	Empty
22	17	Seventh Segment (rev.)	240.0	-6.3	3.0	20.0	-18.0	20	Empty
23	18	Sixth Segment (rev.)	200.0	6.3	2.0	20.0	-20.0	22	Empty
24	19	Fifth Segment (rev.)	300.0	0.0	1.5	22.0	0.0	18	Empty
25	20	Fourth Segment (rev.)	200.0	6.3	1.0	18.0	-20.0	18	Empty
26	21	Third Segment (rev.)	200.0	6.3	1.0	18.0	0.0	15	Empty
27	22	Second Segment (rev.)	180.0	0.0	2.0	15.0	-20.0	15	Empty
28	23	first Segment (rev.)	300.0	-10.0	3.0	15.0	-20.0	15	Empty
29	24	Spot to load (rev.)	50.0	0.0	2.2	15.0	0.0	0	Full
30									

Fig-2 haulage segment details (Talpac)

The maximum and final velocity was recorded from the most reliable truck that is [truck number 7334]. According to the assistant mine manager in charge of supervising the material transportation, the curve angle is calculated based on the radius of curvature, and also it has been found in total that they were five turning points, from the loading point. We can see from [fig 2], the maximum rolling resistance is 3 and that though is for the highest-grade resistance, and the minimum is 1.5 for the downhill grade assistance, this is based on the rolling resistance rating given by the software [Fig 3], that means that the truck exerted high rimpull force at high gradient and more energy is utilized at that level especially when full.

Rolling Resistance Table

Table: Default

	Haulroad Condition		
	Poor	Average	Good
Around Loader	4.5	3.0	2.2
Bench Floor	3.7	2.5	1.9
Pit Ramp	3.7	2.5	1.9
Main Haulroad	3.0	2.0	1.5
Dump	3.7	2.5	1.9

OK

Fig 3-Rolling resistance as per Talpac

Fig 4. gives the Talpac cycle time distribution for the loader, which means that a mean value of 30 second was used to calculate shovel performance.

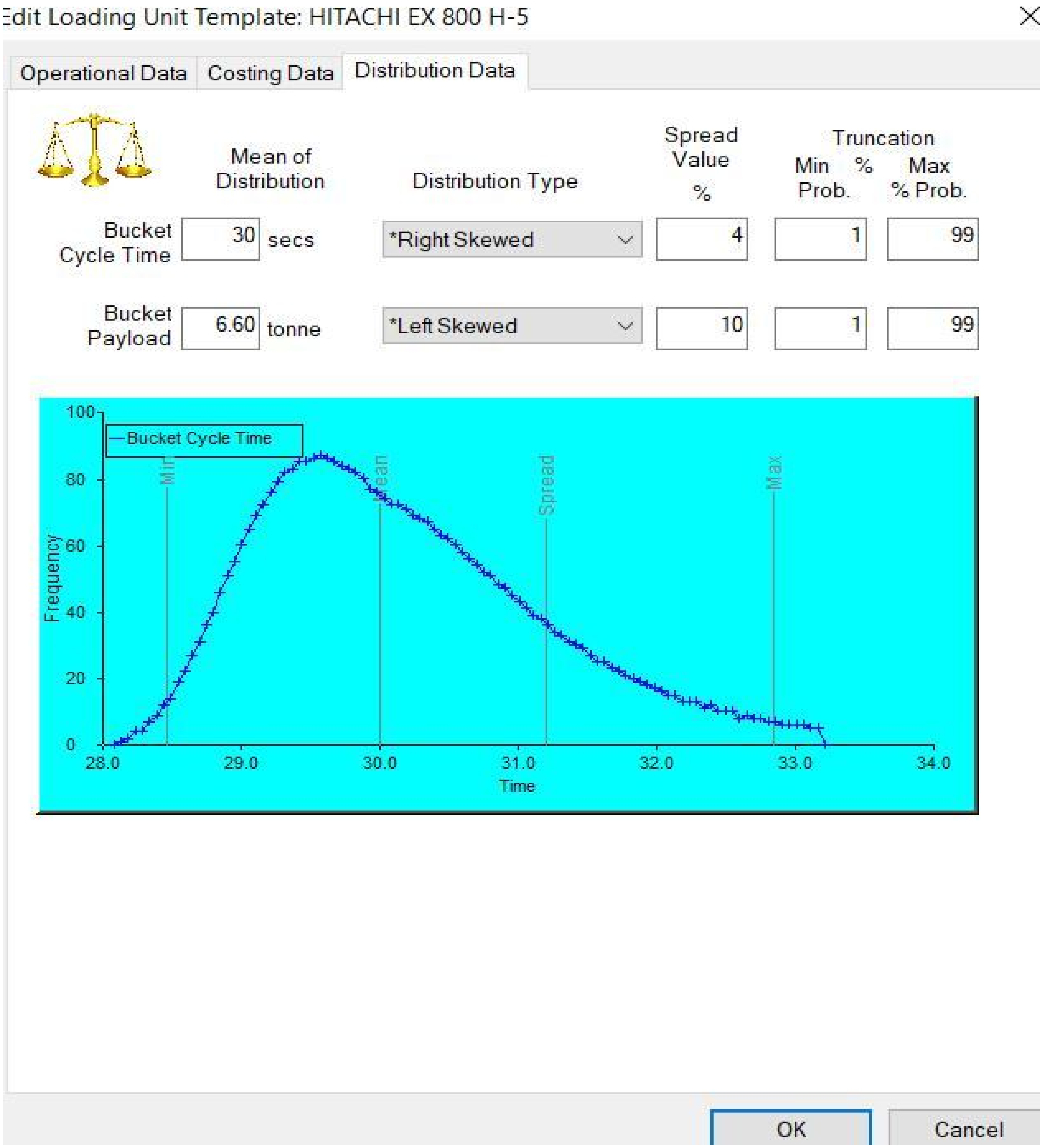

Fig 4. bucket cycle time distribution of Hitachi Ex 800 H-5

$$\text{Performance}= \frac{\text{Cycle time}-\text{speed losses}}{\text{Cycle time}} * 100$$

From the above performance equation, it is possible to determine the speed losses in the shovel, the performance can be found which correspond to the machine availability. Knowing the speed losses, shows the inherent capability of the machine.

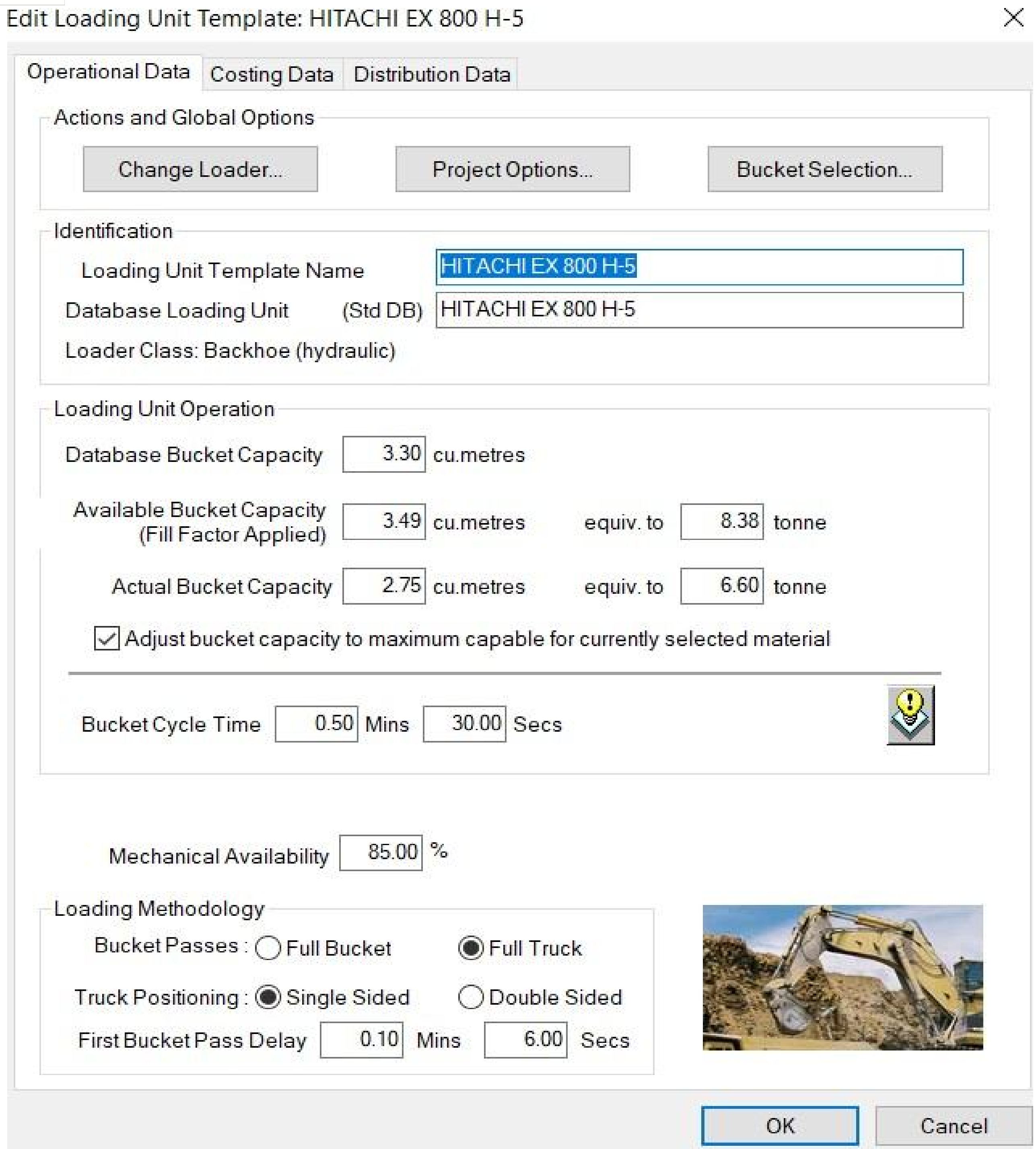

Fig 5. operational data of the shovel (Talpac)

From [Fig 5] the performance or availability of the machine is found to be 85%. Therefore, the speed losses can be determined from the Loose Density equation .

Speed losses= bucket cycle time- performance*bucket cycle time

=30-0.85*30= 4.5

speed loose for a cycle is 4.5 seconds which shows that the operating condition of the shovel is efficient and effective.

All the parameters related to the input parameters have been inserted in the Talpac truck template, and for confidential reason, some data are not going to be displayed. Fig 6 depict the data related to the payload and motor power.

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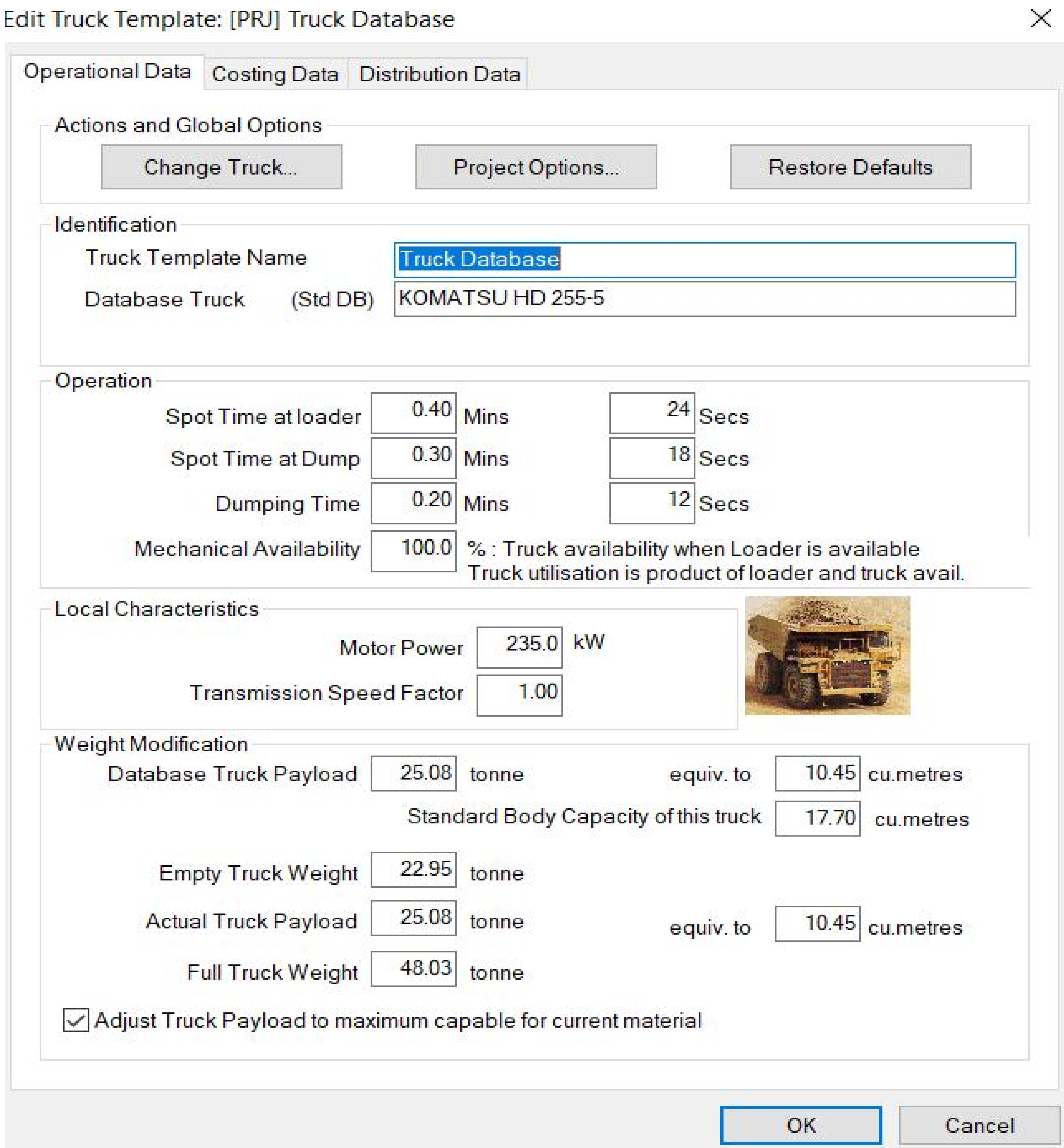

Fig 6 Truck Template (Talpac)

This resume all the input parameters used in this simulation software. Talpac conducts two types of simulation, first is a quick estimate and the second is a full simulation. Full simulation make use of stochastic (varying) and deterministic (fixed) data and as a result, is able to incorporate the effects of queuing on fleet productivity. Whereas, the quick estimate is carried out using only deterministic (fixed) data and produces broad estimates of fleet productivity.

In this case of optimization, in order to obtain the most realistic result we shall be conducting a full simulation. Before the simulation commences, all the parameters incorporated by are shown in the following excel file in annexure 1.

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Annexure 1 shows all the parameters of both loader and hauling unit including their stochastic variable and costing parameter. These are the parameter Talpac considered during a simulation process in providing a realistic result.

After confirming all the parameter, Talpac will provide a loading analysis of the truck, meaning as per the shovel-truck combination provided, number of passes required for loading the truck, the nominal truck capacity which is the volume of loose material that the truck tray is capable of holding and it's a incorporated in Talpac truck database.

Truck 1: [PRJ] Truck Database				
Nominal Truck Capacity	17.70	17.70	17.70	cu.metres
Nominal Truck Capacity	14.16	14.16	14.16	bcm
Material Insitu Bank Density		3.00	3.00	tonnes/cu.m
Material Insitu to Truck Tray Swell		1.25	1.25	
Maximum Volume Truck Payload		42.48	42.48	tonne
Maximum Weight Truck Payload	25.08	25.08	25.08	tonne
Actual Truck Payload		25.08	25.08	tonne
Actual Truck Payload		10.45	10.45	cu.metres
Loading Unit: [PRJ] HITACHI EX 800 H-5				
Bucket Capacity (Heaped)	3.30	3.49	3.49	cu.metres
Material Insitu Bank Density		3.00	3.00	tonnes/cu.m
Material Insitu to Loading Unit Bucket Swell		1.25	1.25	
Bucket Fill Factor (Heaped)		1.06	1.06	
Maximum Volume Bucket Payload		8.38	6.60	tonne
Bucket Construction Rating		0.79	0.79	tonnes/cu.m
Bucket Weight		2.62	2.62	tonne
Maximum Suspended Load	9.22	9.22	9.22	tonne
Maximum Weight Bucket Payload		6.60	6.60	tonne
Actual Bucket Payload		6.60	6.60	tonne
Actual Bucket Payload		2.75	2.75	cu.metres
Number of Passes to Fill Truck		3.80	3.80	

Table-3 Input Database (Talpac)

So here, based on loading analysis, the important parameters to consider are the number of passes to fill one truck which should not be more than approximately four (4) passes, and the actual nominal truck capacity that is given in [table 3] to be 17.70 cu. meters.

The next stage consists of simulating and analyzing the result of simulation, In the next section result of the analyzing shall be explain, and comparison of actual field study and the result obtain from our simulation.

IV. PROBLEM IDENTIFICATION

Based upon a thorough literature study it has been found that many problems are associated with truck-shovel combination system such as equipment selection and their performance evaluation (matching factor, cycle time, allocation, queuing, loading time etc.). Various methods have been employed to model shovel-dumper system. Some of these methods relied on empirical rules or trial and error (heuristic approach), and some are highly mathematical requiring significant computational effort. None of these methods have been found to satisfy all the aspect associated with the system because they do not consider all the features of truck and shovel system.

The limitations in the current research on truck-shovel systems in open-pit mining are
Few details are considered in truck-shovel models. Considering more details make the models complicated, which in return means that more time, money and computer memory is needed to find a solution.
The stochastic nature of the truck-shovel systems is usually treated as deterministic. This weakness is mostly seen in mathematical programming techniques.
In almost all of the literature, the system is modeled based on the shovel production requirement (shovel's hourly production rate). With this approach, the shovels are assumed to work continuously and the main focus is on truck operation.
In almost all of the literature, the source of material is defined as a mining zone or a mining-face. This approach treats each zone as a single complete unit that has single grade and tonnage characteristics. This imposes the assumption that all blocks in a mining-zone are identical.
A huge portion of research focuses on the truck-shovel system as a closed system. Almost no research considers the interactions with other systems in the mine such as processing systems.

V. CONCLUSIONS

After a thorough literature study, the different factor which impact the productivity of fleet equipment combination were identified, but the scope of this study is limited to conduct a life study using a simulation software and compare it with actual cycle time, as result to identify the factor which are affecting the actual cycle time. The speed losses in the hauling unit were also determined and based on the result of our simulation we have found that the fleet are being utilized effectively. The prove to this statement is that, they were able to achieved the production target priory to the end of the financial year. Nowadays, there are many ways to optimize the fleet equipment, however despite of the availability of large number of optimization tool, none of these methods satisfies the condition of entire system. This is mostly due to the stochastic nature the equipment and because of the heterogeneous nature of mine conditions, this statement also has been confirmed in the result of our simulation. The issue of truck dispatching strategy in an open pit mine does not date from today, as the mine deepened, and increase in number of faces, the need of optimization increase becomes crucial. Heuristic approach has not been found to be optimal in many cases, especially large open pit mine. The heuristic approach does not consider the production target, as the demand increases, the mining industries need a scientific or mathematic approach which take the various operational factors into account as to achieved an optimal ore wining. Mixed Integer Linear Programming model is one of the approaches which is commonly adapted by most of the open pit mines, this is due to it flexibility, and the fact that it considers the operational factor such as production target, number of working faces and so on, also the concept can be applied in any operating condition, small- or large-scale mining. The MILP model has been successfully applied in many mines, and resulted in a significant saving, as almost 50 to 60% of the overall mining cost are spent on fleet equipment, therefore a small saving in operating cost is consider to be an achievement. Finally, even though our model is theoretical model for homogeneous fleet equipment, since it obeys strictly the basic requirement for a stochastic model, therefore we can conclude that it can achieve a reduction not less than 10% of the haulage operating cost.
In a surface mine operation, the need of optimizing the fleet equipment is essential, because the haulage operation cost consist of 50 to 60 percent of overall mining cost. Various methods are being used nowadays, among the effective and successful method is Queuing theory. The queuing theory is not just an empirical approach, rather it helps in measuring the performance of haulage equipment (loader and hauler), which are very important in transferring of mineral form loading face to dumping face. Queuing theory study the following measuring parameters such as; waiting time, queue length, shovel utilization, shovel productivity per hour, and other properties. In this case study, the queuing model (M/M/1) along with finite calling population was applied to evaluate the performance of fleet equipment deployed.
From queuing model, the asset evaluation is easier compare to mathematical or heuristic approach, from the arrival rate and service rate, the system analyzing can be picturized and assessed whether the to performance is up to norm or not for sound decision making. Queuing model allowing to know if the system is over-trucking or under-trucking by looking the waiting time in line and system, it will help in removing or adding of truck in optimizing the tonnage transported, also by analyzing time spent in the system it will help in the idle time of trucks.
In this thesis, the cost factors associated the fleet equipment was not taken into consideration, that is because, the mine has kept it to be confidential. From the result of queuing model, we can see how busy is the shovel, which contribute significantly to the productivity in mine. A good shovel utilization should be above 70% in a stable working condition.

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REFERENCES

[1] Ghorai, U. (n.d.). PRODUCTION OPTIMIZATION AND SIMULATION OF LARGE OPEN CAST MINES UTTAM GHORAI PRODUCTION OPTIMIZATION AND.

[2] Bastos, G. S. (2016). Thesis presented to the Faculty of the Department of Graduate Studies OPEN-PIT MINING. (June). https://doi.org/10.13140/RG.2.1.1371.8647

[3] Dembetembe, G., & Mutambo, V. P. (2018). Optimisation of Materials Handling Fleet Performance at Nchanga Open Pit First Zambia National Conference On Geology

[4] Mining , Metallurgy and Groundwater Resources : The Future Mining in Zambia Held at Mulungushi International Conference. (November). https://doi.org/10.13140/RG.2.2.11532.36483

[5] Subtil, R. F., Silva, D. M., & Alves, J. C. (2011). A practical approach to truck dispatch for open pit mines. 35th APCOM Symposium - Application of Computers and Operations Research in the Minerals Industry, Proceedings, (January), 765–777.

[6] Eskandari, H. (2019). Simulation and optimization of haulage system of an open-pit mine Simulation and Optimization of Haulage System of an Open-Pit Mine. (July 2013).

[7] Nguyen, H. (2019). DETERMINATION OF SHOVEL - TRUCK PRODUCTIVITIES IN OPEN - PIT MINES. (November 2014).

[8] Lashgari, A., Yazdani, A. R., & Sayadi, A. R. (2010). Methods for Equipments Selection in Surface Mining ; review. (April), 26–28.

[9] Dindarloo, S. R., Osanloo, M., & Frimpong, S. (2015). A stochastic simulation framework for truck and shovel selection and sizing in open pit mines. Journal of the Southern African Institute of Mining and Metallurgy, 115(3), 209–219. https://doi.org/10.17159/2411-9717/2015/v115n3a6

[10] Hai, D. V. U., & Masniyom, M. (2016). APPLICATION OF QUEUING THEORY IN ANALYSING SHOVEL-. (2), 42–45.

[11] QUeuing _model 3.pdf. (n.d.).

[12] Submitted, T., & Fulfillment, P. (2016). Optimization of Truck and Shovel for Haulage System in the Cao Son Mine , Viet Nam using Queuing Theory Dang Vu Hai Degree of Master of Engineering in Mining Engineering Copyright of Prince of Songkla University.

[13] Trivedi, R., & Rai, P. (2016). Shovel-truck optimization study in an opencast mine - A queueing approach. (June 1999).

[14] Afrapoli, A. M., Tabesh, M., & Askari-nasab, H. (2019). A multiple objective transportation problem approach to dynamic truck dispatching in surface mines. European Journal of Operational Research, (xxxx). https://doi.org/10.1016/j.ejor.2019.01.008

[15] Samavati, M. (2017). New Long-term Production Scheduling Methodologies for Open- pit Mines. (February).

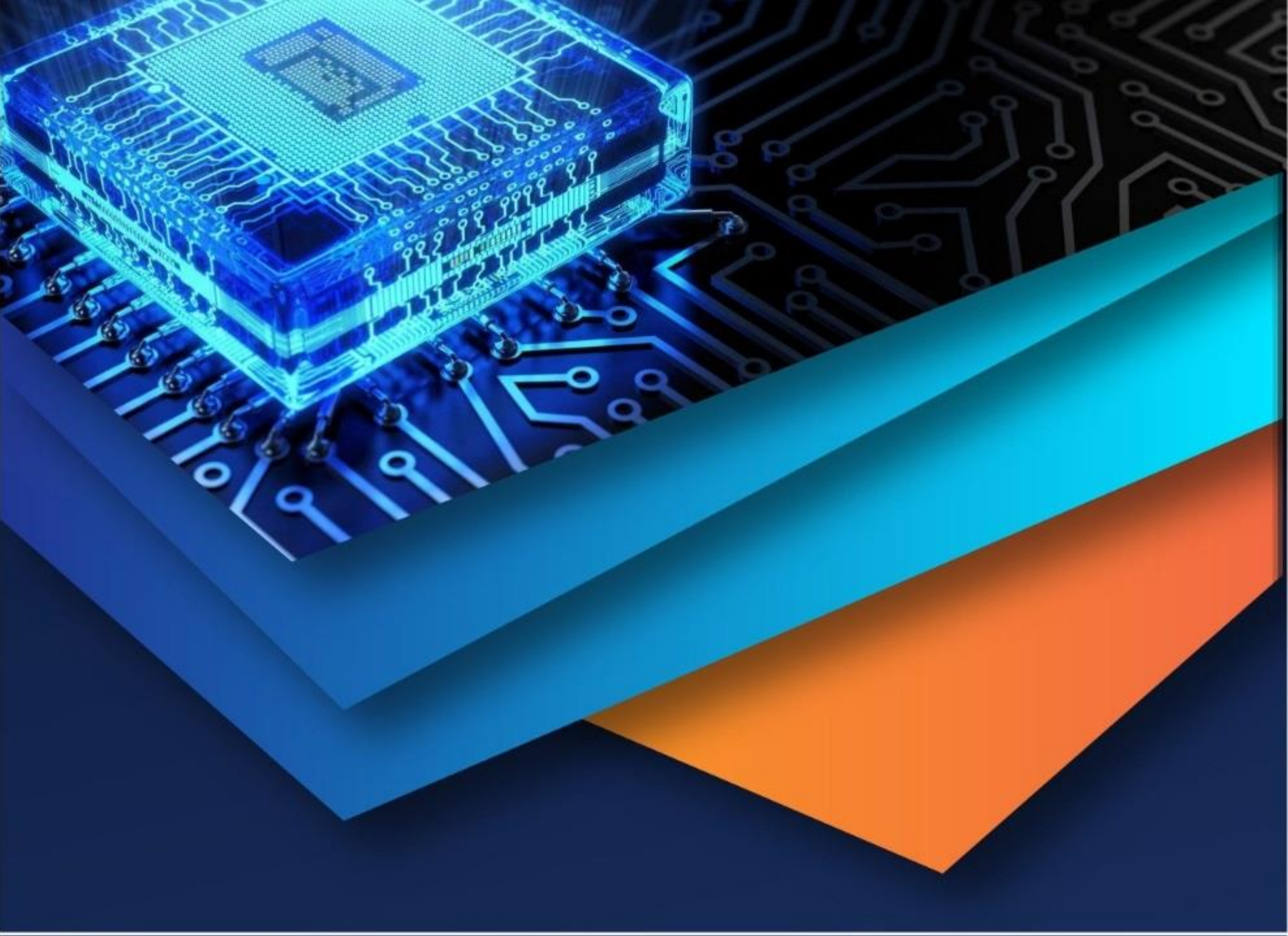
[16] Submitted, A. T., Partial, I. N., Of, F., For, R., Degree, T. H. E., Technology, B. O. F., & Kumar, A. (n.d.). Production Scheduling and Mine Fleet Assignment Using Integer Programming A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE Production Scheduling and Mine Fleet Assignment Using Integer Programming.

[17] B, A. T., A, I. M., & Mariam, U. (2018). Application of Queuing Theory to Larfarge Cement Transportation System for Truck / Loader Optimazation. 2, 167–178. https://doi.org/10.31031/AMMS.2018.02.000528

[18] Fisonga, M., & Mutambo, V. (2017). Optimization of the fleet per shovel productivity in surface mining: Case study of Chilanga Cement, Lusaka Zambia. Cogent Engineering, 4(1), 1–16. https://doi.org/10.1080/23311916.2017.1386852

[19] Kumar, N. S. H., Choudhary, R. P., & Murthy, C. S. N. (2019). Evolution of the probability distribution function of shovel – dumper combination in open cast limestone mine using RWB and ANN : a case study. Modeling Earth Systems and Environment, (August).

[20] Koryagin, M., & Voronov, A. (2017). Improving the organization of the shovel-Truck systems in open-pit coal mines. Transport Problems, 12(2), 113–122. https://doi.org/10.20858/tp.2017.12.2.11



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