Comparative Performance Study of Mine Trucks by Overall Equipment Effectiveness (OEE)

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Abstract – *As the global expansion in technology and demand for metal and mining products the open-pit and underground mines in India have gradually raised their production rate by using large capacity equipment's which comprises intensive capital investment. One way to improve productivity is to utilize equipment as efficiently as possible; therefore, the precise estimate of equipment effectiveness is very crucial so that can be improved. Overall Equipment Effectiveness (OEE) is a well-known measurement method, which accounts performance, availability and quality for the assessment of equipment effectiveness in production industry. It identifies roots of time losses for all operations and introduces procedure to record time losses. The procedure to estimate OEE of trucks has also been presented via numerical analysis.*

Key Words**: OEE, Mining, Time Losses, Equipment Utilization**

1. INTRODUCTION

The rise in digitalization and automation, magnified by multiplication in the size and capacity of equipment over the years has extremely changed the concerns of equipment ineffectiveness. At present economic situations, severe worldwide competition, environmental guiding principle and a constantly improving focus on safety are also causing management to consider resourceful and creative methods to govern effectiveness of their equipment so necessary precautions can be taken to increase the effectiveness of their equipment and to reduce the overall production cost.

Mining is a very capital-intensive industry, and it is known fact that the equipment utilization and precise estimation of its utilization are very crucial since management want to utilize their equipment as efficiently as possible to get an early return on their investments as well reducing overall production cost. The aim of this article is to present a method, which is widely accepted in manufacturing industries, used in measuring overall effectiveness of equipments known as Overall Equipment Effectiveness (OEE).

An OEE solution enables management to reach world-class status. More precisely, it can deliver benefits in three key areas:

1. **Equipment:** Reduced equipment breakdowns and maintenance costs, enhanced management of the equipment life cycle
2. **Personnel:** Labour efficiencies and improved productivity by looking into operations and empowering operators
3. **Process:** Increased in productivity by recognizing bottlenecks
4. **Quality:** Increased rate of quality, reduction in scrap

2. WHAT IS *OVERALL EQUIPMENT EFFECTIVENESS (OEE)*?

OEE is the golden standard for measuring maintenance and manufacturing productivity. Simply say – it identifies the percentage of maintenance and manufacturing time that is actually productive. An OEE score of 100% in production industry means you are maintaining equipments as per schedule, with no breakdowns. In the area of OEE that means 100% quality (maintenance), 100% performance (as fast as possible), and 100% availability (no breakdowns).

OEE is an elementary tool that will help management to quantify the effectiveness of their equipment. It takes the most common and vital sources of productivity loss, which are called ***six big losses*** and given in Table A. These losses are quantified as availability, performance and quality in order to estimate OEE as given in equation (I).

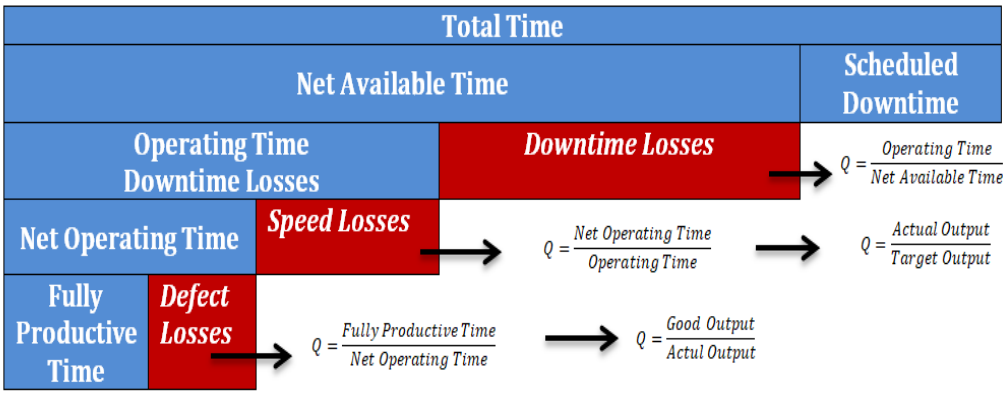
$$OEE = Availability \times Performance \times Quality \quad \text{... (I)}$$

Table A- Six Big Losses

Factor	Six Big Loss Category	OEE Loss Category	OEE Factor
Mechanical	Equipment Failure	Downtime Losses	Availability (A)
Human	Setup and Adjustment		
Operational	Idling and Minor Stoppages	Speed Losses	Performance (P)
Mechanical or Operational	Reduced Speed		
Mechanical	Reduced Yield	Defect Losses	Quality(Q)
Operational	Quality Defects		

The factors considered in equation (I) are generally calculated as shown in Table B. For machines to operate effectively, it needs to achieve high levels of performance against all three of these parameters.

Table B- OEE Parameter



Availability takes into account ***"downtime losses"*** which comprises any events that stopovers planned production for a considerable length of time. This is usually due to equipment breakdowns, failure of timely deliver, improper checks etc. Then, availability is determined as follows:

$$Availability = \frac{Net\ Avaiable\ hours - Downtime\ Losses}{Net\ Available\ Time} \times 100 \ldots\ldots (II)$$

Performance takes into consideration ***"speed loss"***, which includes any reasons that cause the equipment to run less than the maximum possible speed planned. Reasons for that can be operator inefficiency, and job and environmental conditions. Then performance is determined as follows:

$$Performance = \frac{Operatatimg\ Time - Speed\ Losses}{Operating\ Time} \times 100 \ldots (III)$$

Quality takes into account ***"product loss"***, which is determined as follows:

$$Quality = \frac{Net\ Operating\ Time - Defect\ Losses}{Net\ Operating\ Time} \times 100 \ldots (IV)$$

The next step after the estimation of OEE is to compare it with the standard values. Accepted standard value for both production and manufacturing industries is about +85%. If the estimated OEE is below the standard value, then system should be assessed for improvement. It is also apparent that the successful computation of OEE rest on on the ability to gather necessary data. Unreliable or scanty data may not replicate real equipment utilization. It is very crucial to recognize that every single loss classified corresponds to an equipment state. One topic needs to be discussed in the estimation of OEE is **overall time**.

This type of overall time estimation is known as filling/loading time-based method and most of the previous estimation carried out on this base. But, this method results in overestimation of OEE and may not replicate the real equipment

utilization. Another approach namely calendar time-based approach is more preferable to filling/loading time-based approach since it measures real equipment utilization. Calendar time is hypothetical calendar time during which company owns the equipment.

3. OEE FOR MINING EQUIPMENT

Mining Industry have different challenges to go through wherein in a process cannot be streamlined. It differs from manufacturing industry. Therefore, it is essential to develop equipment's own classification structure for the losses, which should be allied with the parameters in equation (I).

The necessary data classification to be collected will vary from equipment to equipment. In addition to that, it is more difficult to gather data for mining equipments due to following reasons:

- Mining is a cycle based operation of drill-blast, load, haul and dump. Hence, the productivity of equipments used in each cycle depends on the productivity of preceding equipment. That means if the initial equipment in the cycle remains unutilized then the whole cycle of equipments use is impacted.
- The capacity of mining equipment is large and the consequence of utilization on total production is very big.
- The physical environment under which mining equipment operates is less supportive for equipments and machines.
- The operating environment of the mine is constantly changing with numerous unknowns that can put impact on the equipment utilization drastically.
- The controllable parameters by management like dust, water sprinkling and illumination can also impact on the utilization of equipment.

In this study, OEE of trucks have been measured since they are the main equipments for the most of the Open pit and underground mines.

5. OEE CALCULATION FOR TRUCKS (OFF-ROAD)

Trucks are used in open pit mining as primary hauling equipment. Their performance and production controls the total output of operation as well as loaders. As it is said before that the time losses classification for truck is also different. Therefore, the possible time losses causes are defined as follows:

Loss Classification	Description
Non-Scheduled Time	Time duration for which equipment not allocated to operate. Time spent for periodic maintenance of truck.
Scheduled Maintenance Time	Time spent on breakdown.
Unscheduled Maintenance Time	Time spent for setup and adjustment.
Setup And Adjustment Time	Equipment is ready but no operator (such as lunch break).
Idle Time Without Operator	Time duration for which truck waits to get position to be loaded
Truck Waiting Time	
Loading Time Loss	Time which truck waits to be loaded.
Time Losses Due To Job Conditions	Time loss due to management, supervision, climate and job conditions
Speed Loss	Time loss due to the equipment that is operating under the standard speed
Quality Loss	That is equivalent to unqualified products and depends on the fill factor of loader.

The above time-loss classifications are calendar time-based approach. Thus, the procedures to compute OEE of truck can be represented as given in Table 3.

Table C- Procedures for estimation of OEE via calendar time-based approach

TOTAL TIME (TT) 24 (hours/day)x 7(days/week)		LOSSES	OEE FACTOR
Actual Available Time (AAT)	***Availability Losses***	Non-scheduled time Scheduled maintenance Unscheduled maintenance Setup and adjustment • Idle time • Loader waiting time	$Availablity = \frac{Actual\ Available\ Time}{Total\ time}$
Net Production Time (NPT)	***Performance Losses***	• Loading time Job condition loss Speed loss	$Performance = \frac{Net\ Production\ Time}{Actual\ Available\ time}$
Valuable Production Time (VPT)	***Quality Loss***	• Quality loss	$Quality = \frac{Valuable\ Production\ Time}{Net\ Production\ time}$ $Quality = \frac{Volume\ Average\ Load}{Actual\ Bucket\ Capacity}$

It should be noted that quality loss in Table C is not actual loss time. It is just to represent the amount of material which truck is supposed to haul, but it is not hauled due to loader filling factor. Therefore, quality loss is considered as truck filling factor.

Numerical Example for Truck Operation: The Table D contains hypothetical data, to be used for OEE calculation of a truck. These data represent time line of items during one month of truck operation.

Table D- Time Lengths of Items for a Truck Operation

Item	Description	Time (hours/month)
Total time	24 hours/day X 30 days /month	720
Non-scheduled time losses	2 days off	48
Scheduled maintenance time losses	2 days	48
Unscheduled Maintenance time losses	Breakdowns	65
Setup and adjustment time losses	30 minutes/shift	5.25
Idle time losses	40 minutes /shift	7
Truck waiting time losses	30 minutes/shift	5.25
Loading time loss	40 minutes/shift	7
Job conditions	Equipment did not work due to operational reasons	25
Speed loss	30 minutes/shift	5.25
Quality loss	Filling factor (87%)	
Truck Capacity	63 ton	
Ideal production	45 minutes per trip	

By using data given in Table C and relations given in Table D, OEE estimation of loader has been estimated. The calculations are given in Table E.

Table E- OEE Assessment of a Truck

		Calendar time-based approach	Filling/Loading time-based approach
Total time		720 hours	(720 – 48-48) =624 hours
Availability	**=**	AAT / TT	AAT / TT
	=	(720 – (48+48+65+5.25+7+5.25)) / 720	(624– (48+5.25+7+5.25)) / 624
	=	0.7003	0.8080
Performance	=	NPT /AAT	NPT /AAT
	=	(541.50– (7+25+5.25) / 541.50	(541.50– (7+25+5.25) / 541.50
	=	0.931	0.931
Quality	=	0.87	0.87
OEE	**=**	Availability x Performance x Quality	Availability x Performance x Quality
	=	0.7003 x 0.931 x 0.87	0.8080x 0.931x 0.87
OEE	**=**	**0.567 (%57)**	**0.654 (%65)**
Total Production	=	((720 x 60) /45) x 63 x 0.567 **=34,292.16 ton**	= ((624 x 60)/45) x 63 x 0.654 **= 34,280.06 ton**

As it can be seen in Table (E) that the OEE of truck for filling/loading time based approach and calendar time-based approach is 65 %, and it is 56 % respectively.

6. CONCLUSIONS

Productivity of equipment can only be enhanced and controlled successfully if a correct performance measurement system is used. *Overall Equipment Effectiveness (OEE)* is a well-known method to measure performance of production equipment in manufacturing industries and adapted for mining industry in this article. It objectives is to identify unproductive time losses inside the system and these time losses impacting availability, performance and quality. This article has shown that, what are the possible time losses for utilizing mining equipments? More specifically trucks, and how they can be used in the calculation of OEE.

Filing/Loading time-based approach provides higher OEE values than Calendar time-based approach. Hence, it is important to declare which approach is used when one talks about OEE of any specific equipment. The importance of proper data collecting system to estimate OEE is also give emphasis to. If data are not properly collected then the resulting OEE will not be significant. Most of the equipment producers provide data collecting system for their equipments, the management just needs to classify them according to definitions.

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