CHAPTER-6

CHAPTER-6

APPLICATIONS

6.1 FIELD APPLICATION

The developed methods for performance measurement and fixing benchmark level of performance for dump trucks may be a useful tool to the management in decision making, e.g., comparing performances of dump trucks, dragonizing causes of low performance, etc. The following sections illustrate these applications with the help of case studies.

6.2 COMPARISON OF PERFORMANCE OF DUMP TRUCKS OF TWO DIFFERENT GROUPS

Out of all studied dump trucks deployed for coal transportation in NCL surface mining projects, ten dump trucks have been selected for this comparison study. These dump trucks have been primarily grouped into two:

Group A: It consists of five dump trucks (D-1231, D-1232, D-1233, D-1234 and D-1235), manufactured by company A, of 100 ton capacity and operating in the mine since December 18, 2012. Figure 6.1 shows one of these dump trucks.

Group B: It consists of five numbers of dump trucks (D-10628, D-10629, D-10630, D-10631 and D-10632), manufactured by Company B, of 100 ton capacity and operating in the mine since October 1, 2014. Figure 6.2 represents one of these dump trucks.

Figure 6.1 Group-A dump trucks

Figure 6.2 Group-B dump trucks

Various performance records of these dump trucks for three years (January 2015 to December 2017) have been collected and analyzed. Table 6.1 and Table 6.2 detail the procedure for calculation of OEPI and its component for the year 2017 of dump trucks D-1231 and D-10628 respectively. Comparison of OEPI values of Table 6.1 and Table 6.2 reflects that the dump truck D-10628 performs better than the dump truck D-1231.

Table 6.3 presents the year-wise average and overall average performance status of both the Group-A and Group-B dump trucks for three years period starting January 2015 to December 2017. It shows that average availability and utilization figures vary between 54% - 62% and 47% - 52% respectively for Group-A dump trucks and 69% - 71% and 63% - 65% for Group-B dump trucks during the study period. OEPI has been calculated taking estimated values of 95% for capacity performance (C). Environmental performance is 75% for Group-A dump trucks and 83% for Group-B dump trucks. OEPI varies from 18% - 22% for Group-A dump trucks and 33% - 39% for Group-B dump trucks. Availability and utilisation figures are much less than the other two components of OEPI and are primarily responsible for low OEPI values. Low availability indicates high loss of time in breakdown and maintenance whereas utilization factor decreases due to increase in idle hours. Poor utilization factor indicates that the equipment is available, but idle may be due to planning or related issues and not a machine issue. There is also some scope for improvement of capacity performance and environmental performance for maximizing the OEPI of the dump trucks. Performance figures of Table 6.3 also echo the out performance of Group-B dump trucks over Group-A dump trucks. Many factors influence the performance of dump trucks as discussed in Chapter 3. Age of the equipment may also influence the performance of dump trucks. Table 6.3 reports a decreasing trend in performance of dump trucks with age.

Table 6.1 Calculation of A, U and OEPI of Dump Truck (D-1231)

Month (2017)	TT	WRK	MNT	BDN	IDL	A%	U%	CL (Kg)	C	%CO_2	E	OEPI
Jan.	744	305	87	127	225	0.71	0.58	2410	0.95	9	0.75	0.29
Feb.	672	245	58	230	139	0.57	0.64					0.26
Mar.	744	110	180	402	52	0.22	0.68					0.11
Apr.	720	307	174	145	94	0.56	0.77					0.30
May	744	117	158	279	190	0.41	0.38					0.11
Jun.	720	290	95	218	117	0.57	0.71					0.29
Jul.	744	202	143	231	168	0.50	0.55					0.19
Aug.	744	141	93	364	146	0.39	0.49					0.14
Sep.	720	288	96	184	152	0.61	0.66					0.29
Oct.	744	217	69	284	174	0.53	0.56					0.21
Nov.	720	221	138	268	93	0.44	0.70					0.22
Dec.	744	254	179	198	113	0.49	0.69					0.24

Table 6.2 Calculation of A, U and OEPI of Dump Truck (D-10628)

Month (2017)	TT	WRK	MNT	BDN	IDL	A%	U%	CL (Kg)	C	%CO_2	E	OEPI
Jan.	744	512	21	100	111	0.84	0.82	2410	0.95	10	0.83	0.55
Feb.	672	433	69	50	120	0.82	0.78					0.51
Mar.	744	467	45	48	184	0.88	0.72					0.50
Apr.	720	462	32	118	108	0.79	0.81					0.51
May	744	461	52	118	113	0.77	0.80					0.49
Jun.	720	446	30	80	164	0.85	0.73					0.49
Jul.	744	453	91	117	83	0.72	0.85					0.48
Aug.	744	465	36	104	139	0.81	0.77					0.50
Sep.	720	471	32	109	108	0.80	0.81					0.52
Oct.	744	479	48	71	146	0.84	0.77					0.51
Nov.	720	456	29	77	158	0.85	0.74					0.50
Dec.	744	494	56	76	118	0.82	0.81					0.53

Table 6.3 Average A, U and OEPI of different dump trucks for the year 2017, 2018 and 2019

Dump truck ID	For the year 2015, average value of			For the year 2016, average value of			For the year 2017, average value of			Average A, U and OEPI of Dump truck during the study period			Group wise average A, U and OEPI of dump truck		
(100 T)	A	U	OEPI	A	U	OEPI	A	U	OEPI	A	U	OEPI	A	U	OEPI
D-1231	0.50	0.62	0.22	0.69	0.46	0.21	0.67	0.48	0.20	0.62	0.52	0.18	0.57	0.51	0.20
D-1232	0.51	0.57	0.21	0.61	0.42	0.19	0.49	0.43	0.16	0.54	0.47	0.19			
D-1233	0.54	0.61	0.25	0.63	0.48	0.20	0.59	0.47	0.19	0.59	0.52	0.21			
D-1234	0.54	0.62	0.25	0.65	0.55	0.24	0.50	0.35	0.16	0.56	0.51	0.22			
D-1235	0.58	0.50	0.23	0.58	0.54	0.21	0.52	0.49	0.17	0.56	0.51	0.20			
D-10628	0.72	0.66	0.34	0.76	0.73	0.39	0.60	0.55	0.25	0.69	0.65	0.33	0.70	0.65	0.37
D-10629	0.82	0.78	0.50	0.71	0.70	0.42	0.61	0.49	0.24	0.71	0.66	0.39			
D-10630	0.78	0.79	0.49	0.72	0.68	0.41	0.60	0.55	0.25	0.7	0.67	0.38			
D-10631	0.74	0.69	0.44	0.76	0.74	0.43	0.58	0.46	0.21	0.69	0.63	0.36			
D-10632	0.74	0.70	0.45	0.75	0.72	0.42	0.58	0.52	0.24	0.69	0.65	0.37			

6.3 VALIDATION OF RESULTS THROUGH STATISTICAL ANALYSIS

Further analysis of performance data has been carried out to strengthen and add confidence in decision making statistically. Based on the preliminary analysis of performance data the following null hypotheses have been set.

H_{01}: Mean of OEPI differences in the corresponding months of consecutive years of a dump truck ≤ 0

H_{02}: Mean of availability differences in the corresponding months of consecutive years of a dump truck ≤ 0

H_{03}: Mean of utilization differences in the corresponding months of consecutive years of a dump truck ≤ 0

H_{04}: (average performance of Group-B dump trucks - average performance of Group-A dump trucks) ≤ 0.

Whether the performance differences are statistically significant or not has been done with t-test.

6.3.1 Normality Test

The validity of the result of a statistical hypothesis test depends on the nature of the distribution of data. OEPI data for both the groups of dump trucks have been tested for normality with the help of IBM SPSS Statistics 23. A normally distributed data set has the following properties:

Both skewness z-value and kurtosis z-value lie between -1.96 to +1.96.

p-value obtained from the Shapiro-Wilk test is greater than 0.05.

Points in Q-Q plot lie along the straight line.

Box plot becomes approximately symmetrical.

Result of the normality test for both the groups of dump trucks is presented in Table 6.4 and confirms that OEPI data of the Group-A and Group-B dump trucks follow a normal distribution.

Table 6.4 Results of normality test for OEPI of Group-A and Group-B dump trucks

Group-A	Group-B
Skewness z-value = skewness/std. error = 0.127	Skewness z-value = skewness/std. error = -0.149
Kurtosis z-value = kurtosis/ std. error =-0.353	kurtosis z-value = kurtosis / std. error = -1.44
Shapiro-Wilk test, p= 0.323	Shapiro-Wilk test, p= 0.272
Nature of Q-Q plot is a straight line, Figure 6.3 (a)	Q-Q plot is an approximately straight line, Figure 6.3 (b)
The box plot is approximately symmetrical, Figure 6.4 (a)	The box plot is approximately symmetrical, Figure 6.4 (b)

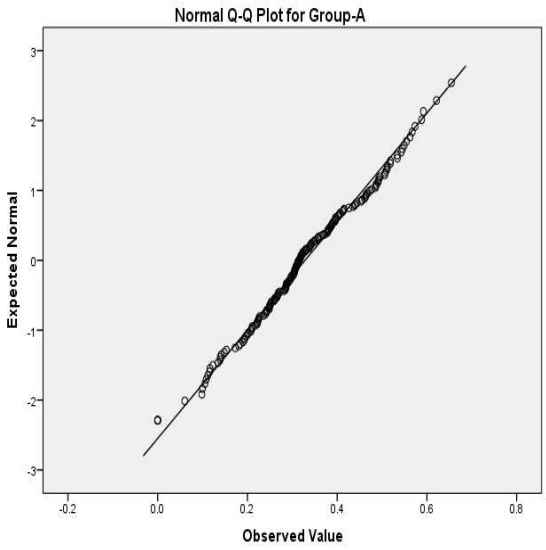

Figure 6.3 (a) Normal Q-Q Plot for Group-A dump truck

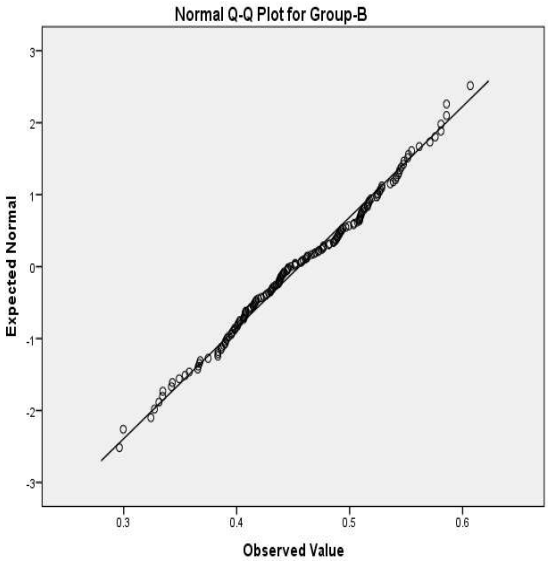

Figure 6.3 (b) Normal Q-Q Plot for Group-B dump truck

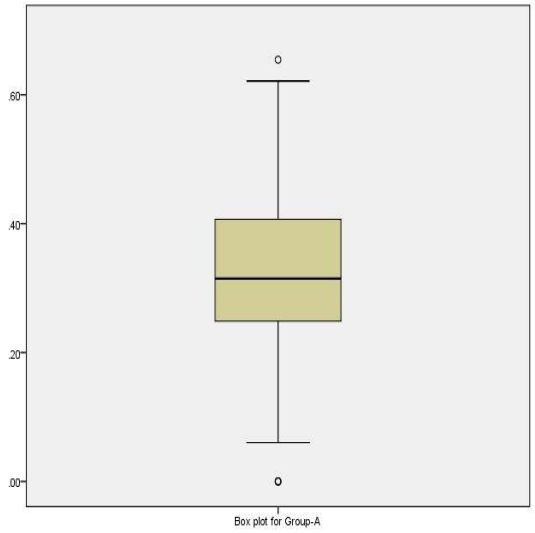

Figure 6.4 (a) Box plot for Group-A dump truck

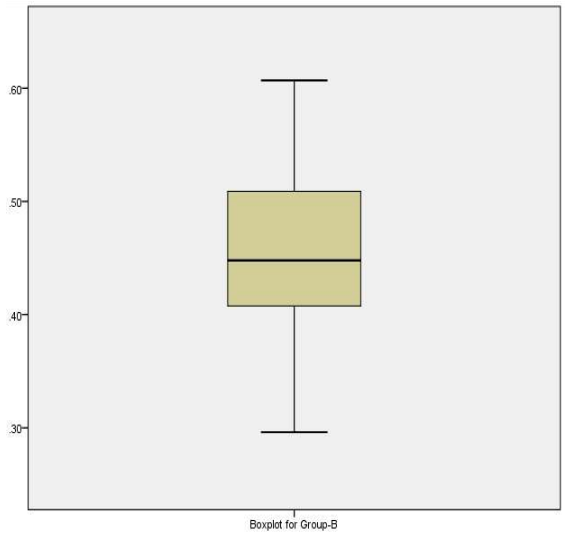

Figure 6.4 (b) Box plot for Group-B dump truck

Similarly, normality tests for the individual components of OEPI i.e., availability and utilization have been carried out, and the results support the normality of data sets.

6.3.2 Effect of operating hours on A, U and OEPI using Paired sample t-test

Whether the mean of differences of performance of a dump truck in corresponding months of two consecutive years > 0, in other words, decrease in performance of dump trucks with age are statistically significant or not has been carried out through paired sample t-test in IBM SPSS Statistics 23.

Paired sample t-tests in SPSS have been performed to assess statistical significance of the performance (OEPI, availability and utilization) decrease with the age of dump trucks. The tested null hypotheses for these cases are:

H_{01}: Mean of OEPI differences in the corresponding months of consecutive years of a dump truck ≤ 0

H_{02}: Mean of availability differences in the corresponding months of consecutive years of a dump truck ≤ 0

H_{03}: Mean of utilization differences in the corresponding months of consecutive years of a dump truck ≤ 0

Table 6.5 Result of paired sample t-test for OEPI for Group-A and Group-B dump trucks

Group	Year	Mean	N	Std. Deviation	Paired Differences					
					Mean	90% confidence interval of OEPI difference		t	df	p
						Lower	Upper			
Group-A	2015 2016	0.3891 0.3218	60 60	0.1380 0.0772	0.0673	0.0376	0.0970	3.79	59	0.0004
	2016 2017	0.3218 0.2514	60 60	0.0772 0.0737	0.0704	0.0507	0.0901	5.97	59	0.00001
Group-B	2015 2016	0.4597 0.4042	60 60	0.1049 0.0953	0.0556	0.0387	0.0724	5.52	59	0.00001
	2016 2017	0.4042 0.3707	60 60	0.0953 0.0809	0.0335	0.0197	0.0473	4.06	59	0 .00015

Table 6.5 presents the result of the paired sample t-test of Group-A and Group-B dump trucks for the OEPI data set. It favours rejection of null hypothesis H_{01} as the mean difference is greater than zero and OEPI of dump trucks in a year is significantly higher than the succeeding year. Result also infers with 90% confidence that OEPI of Group-A dump trucks has reduced between 3.76% - 9.7% in 2016 from 2015 and between 5.07% - 9.01% in 2017 from 2016 whereas these values are 3.87% - 7.24% and 1.97% - 4.73% for Group-B dump trucks respectively. Ageing is marginally faster for Group-A dump trucks from the OPEI decrement aspect.

Table 6.6 Result of paired sample t-test for the availability of Group-A and Group-B dump trucks

Group	Year	Mean	N	Std. Deviation	Paired Differences					
					Mean	90% confidence interval of Availability difference		t	df	p
						Lower	Upper			
Group-A	2015 2016	0.6330 0.5392	60 60	0.20836 0.13384	0.0938	0.0407	0.1468	2.95	59	0.0045
	2016 2017	0.5392 0.4545	60 60	0.13384 0.14409	0.0847	0.0534	0.1159	4.53	59	0.00003
Group-B	2015 2016	0.7835 0.7024	60 60	0.13350 0.15504	0.1594	0.0467	0.1155	3.94	59	0.00022
	2016 2017	0.7024 0.6519	60 60	0.15504 0.13043	0.0505	0.0177	0.0833	2.58	59	0.01255

Table 6.6 gives the result of the paired sample t-test for the availability data set of Group-A and Group-B dump trucks. All p-values are significant at $\alpha = 0.01$ which indicates rejection of null hypothesis H_{02} and agrees that the availability of dump trucks is in decline with age. Analysis of sample data supports with 90% confidence that the availability of Group-A dump trucks has reduced between 4.07% - 14.68% in 2016 from 2015 and for Group-B between 5.34% - 11.59% in 2017 from 2016 whereas these values are 4.67% - 11.55% for Group-A and 1.77% - 8.33% for Group-B dump trucks respectively. Rate of decrease of availability for Group-B dump trucks is comparatively slower than Group-A.

Table 6.7 Result of paired sample t-test for utilization of Group-A and Group-B dump trucks

Group	Year	Mean	N	Std. Dev.	Paired Differences					
					Mean	90% confidence interval of Utilization difference		t	df	p
						Lower	Upper			
Group-A	2015 2016	0.6183 0.6546	60 60	0.1704 0.1976	-0.0363	-0.0753	0.0027	-1.19	59	0.2404
	2016 2017	0.6546 0.6100	60 60	0.1976 0.1373	0.0446	-0.0161	0.1052	1.47	59	0 .1469
Group-B	2015 2016	0.6378 0.6198	60 60	0.1105 0.0956	0.0180	-0.0189	0.0549	0.98	59	0.3335
	2016 2017	0.6198 0.6286	60 60	0.0956 0.1559	-0.0088	-0.0435	0.0259	-0.51	59	0.61336

Similarly, Table 6.7 shows the output of the paired sample t-test for utilization data set. All the p-values are not significant, indicating sample data set do not support to reject the null hypothesis H_{03}. Since the 90% confidence intervals of all the four cases include zero, it cannot be concluded from the present data set that utilization decreases with the age of the dump trucks.

6.3.3 Comparison of Performance of Group-A and Group-B dump trucks using Independent sample t-test

Independent sample t-test has been done with the help of IBM SPSS Statistics 23 for comparing the performance of Group-A dump trucks and Group-B dump trucks. Performance of the two groups of dump trucks at approximately same engine-hours has been compared to block the effect of age on performance comparison of dump trucks. For this comparison study, performance data of the dump trucks at the 4th year of their deployment, i.e., performance data of the year 2016 for Group-A, and of the year 2018 for Group-B have been analyzed. Whether the difference of means of performances of

the two groups of dump trucks is statistically significant or not has been carried out through independent sample t-test in IBM SPSS Statistics 23. The null hypothesis for this case has been taken as

H_{04}: (average performance of Group-B dump trucks - average performance of Group-A dump trucks) ≤ 0.

Independent sample t-test assumes that samples are of equal variance.

Table 6.8 Independent sample t-test (Student's t-test) for Group-A and Group-B dump trucks

	Levene's test for equality of variances		t-test for equality of means			
	F	Sig. (p)	t	df	95% confidence interval of the difference	
					Lower	Upper
OEPI (assumed equal variances)	14.06	0.001	7.39	118	0.0826	0.1432
Availability (assumed equal variances)	32.21	0.001	8.84	118	0.1350	0.2129

Computed t-statistic is (t* = 7.39) > tabulated value for t at the 5% level of significance for 'number of degrees of freedom' 118 ($t_{0.05,118}$ = 1.658). Hence, the observed data reject the null hypothesis in favour of the alternative hypothesis, i. e., the performance of Group-B dump trucks is better than Group-A. Table 6.8 shows that the Group-B dump trucks perform 8.26% - 14.32% better than the Group-A dump trucks. Similar analysis has been done taking the availability data, and it has been found that the availability of Group-B dump trucks is greater than that Group-A dump trucks. For this study, the statistically significant result supports the notion that the mean

availability of Group-B is more than the Group-A dump trucks and likely difference is between 13.50 % - 21.29%.

The availability, utilization and OEPI comparison of group-A and group-B dump trucks are also given below with the help of Figure 6.5 (a), 6.5 (b) and 6.5 (c).

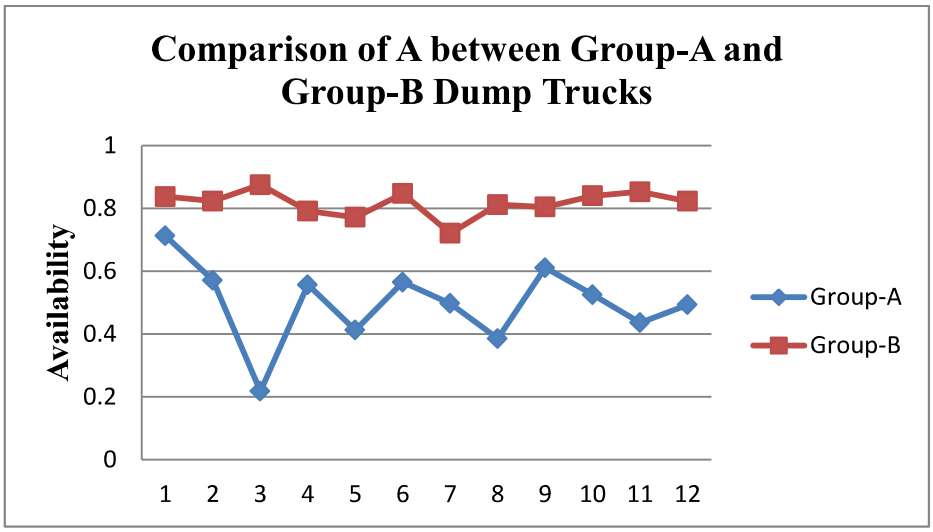

Figure 6.5 (a) Comparison of A between Group-A and Group-B Dump Trucks

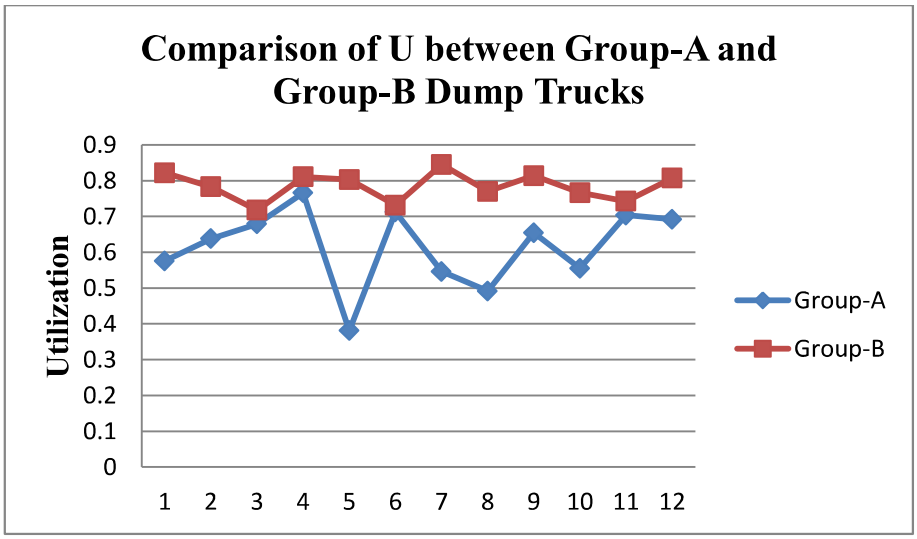

Figure 6.5 (b) Comparison of U between Group-A and Group-B Dump Trucks

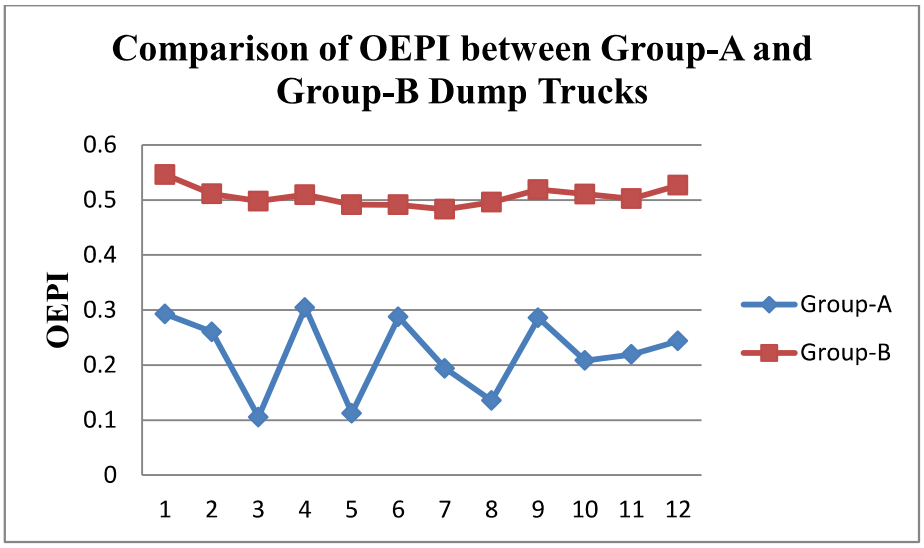

Figure 6.5 (c) Comparison of OEPI between Group-A and Group-B Dump Trucks

The status of OEPI and its components reflects the dump truck performance vis-à-vis the problem areas for further improvements. The most important problem of low OEPI is linked to availability and utilization issues, which are mostly related to dump trucks failure and their maintenance and underused hours. Hence, it is suggestive from the present case study that there is ample scope to improve the system by appropriate maintenance and repair, overall operational and organization planning and design as well as apposite engine maintenance as more diesel consumption results in environmental degradation as well as more expenses on diesel consumption.

6.4 PERFORMANCE COMPARISON OF DUMP TRUCKS OF TWO SURFACE COAL MINES IN INDIA

For comparing the performance of dump trucks of two surface mines of Coal India Limited (CIL) i.e., Mine-I and Mine-II, a case study has been done by selecting 85 T capacity dump trucks from each mine. These dump trucks are of same manufacturer and have approximately equal cumulative operating hours in these mines. Various

performance records of these dump trucks have been analyzed and presented in Table 6.9 and Table 6.10.

Table 6.9 Description of A, U for dump truck: Mine-I, C-255, 85 T

Month (2016)	TT (h)	UT (h)	MNT (h)	BDT (h)	IT (h)	A	U
Jan.	744	132	127	48	437	0.7644	0.2321
Feb.	672	159	240	36	285	0.5890	0.2808
Mar.	744	254	106	55	329	0.7840	0.4352
Apr.	720	264	123	48	285	0.7621	0.4814
May	744	172	89	54	429	0.8082	0.2866
Jun.	720	212	204	40	264	0.6616	0.4451
Jul.	744	179	289	33	243	0.5673	0.4241
Aug.	744	184	71	53	412	0.8337	0.3354
Sept.	720	203	84	53	404	0.8098	0.3070
Oct.	744	232	123	50	315	0.7669	0.4480
Nov.	720	209	60	54	397	0.8421	0.3447
Dec.	744	161	95	55	433	0.7985	0.2705

Table 6.10 Description of A, U for dump truck: Mine-II, C-9931, 85 T

Month (2016)	TT (h)	UT (h)	MNT (h)	BDT (h)	IT (h)	A	U
Jan.	744	253	71	330	90	0.4610	0.7376
Feb.	672	350	40	144	162	0.7356	0.6836
Mar.	744	0	0	744	0	0	0
Apr.	720	453	63	40	164	0.8569	0.7342
May	744	357	21	123	243	0.8065	0.595
Jun.	720	182	140	281	117	0.4153	0.6087
Jul.	744	229	37	120	358	0.7890	0.3901
Aug.	744	189	40	2	513	0.9436	0.2692
Sept.	720	209	24	368	119	0.4556	0.6372
Oct.	744	301	120	116	207	0.6828	0.5925
Nov.	720	274	73	217	156	0.5972	0.6372
Dec.	744	123	123	135	208	0.6532	0.5720

Analysis of performance data has been carried out to strengthen and add confidence in decision making statistically. Whether the performance differences are statistically significant or not has been done with t-test.

The validity of the result of a statistical hypothesis test depends on the nature of the distribution of data. Availability data for both the dump trucks have been tested for normality with the help of IBM SPSS Statistics 23.

Result of the normality test for both the dump trucks is presented in Table 6.11 and confirms that availability data of this Mine-I and Mine-II dump trucks follow a normal distribution.

Table 6.11 Results of normality test of C-255 & C-9931 dump trucks

C-255	C-9931
Skewness z-value = skewness/std. error = 0.858	Skewness z-value = skewness/std. error = -0.342
Kurtosis z-value = kurtosis/ std. error =-1.47	kurtosis z-value = kurtosis / std. error = 0.303
Shapiro-Wilk test, p= 0.052	Shapiro-Wilk test, p= 0.797

Similarly, normality test of utilization data has also been done and results support the normal distribution.

Independent sample t-test has been carried out with the help of IBM SPSS Statistics 23 for comparing the performance of Mine-I dump trucks and Mine-II dump trucks. This test finds whether the difference of means of performances of the two company dump trucks is statistically significant or not. The null hypothesis for this case has been taken as

H_{05}: (average availability of Mine-II dump trucks - average availability of Mine-I dump trucks) ≤ 0.

H_{06}: (average Utilization of Mine-II dump trucks - average utilization of Mine-I dump trucks) ≤ 0.

Table 6.12 Independent sample t-test (Student's t-test) for Mine-I and Mine-II dump trucks

	Levene's test for equality of variances		t-test for equality of means			
	F	Sig. (p)	t	df	95% confidence interval of the difference	
					Lower	Upper
Availability (assumed equal variances)	31.04	0.16	-4.38	22	-0.2031	-0.767
Utilization (assumed equal variances)	6.60	0.012	14.32	22	0.2485	0.3284

Computed t-statistic for availability ($t^* = -4.38$) is less than the tabulated value for t at the 5% level of significance for 'number of degrees of freedom' 22 ($t_{0.05, 22} = 1.717$). Hence the observed data accept the null hypothesis (H_{05}) against the alternative hypothesis, i.e., availability of Mine-II dump truck is lower than Mine-I dump truck and likely the difference is between 7.67% - 20.31%.

Similarly, computed t-statistic for utilization is ($t^* = 14.32$) > tabulated value for t at the 5% level of significance for 'number of degrees of freedom' 22 ($t_{0.05, 22} = 1.717$). Hence, the observed data reject the null hypothesis in favour of the alternative hypothesis, i.e., the utilization of dump truck C-9931 is better than C-255 and likely difference is between 24.85 % - 32.84%.

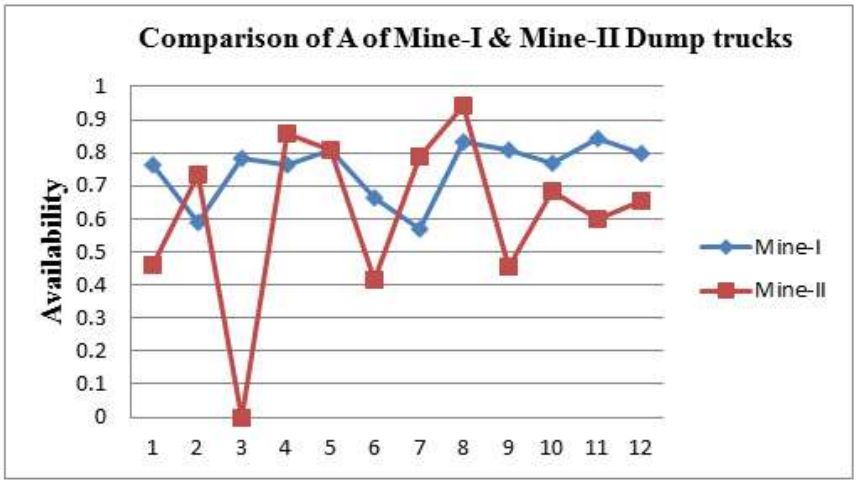

Figure 6.6 (a) Comparison of A of Mine-I & Mine-II dump trucks

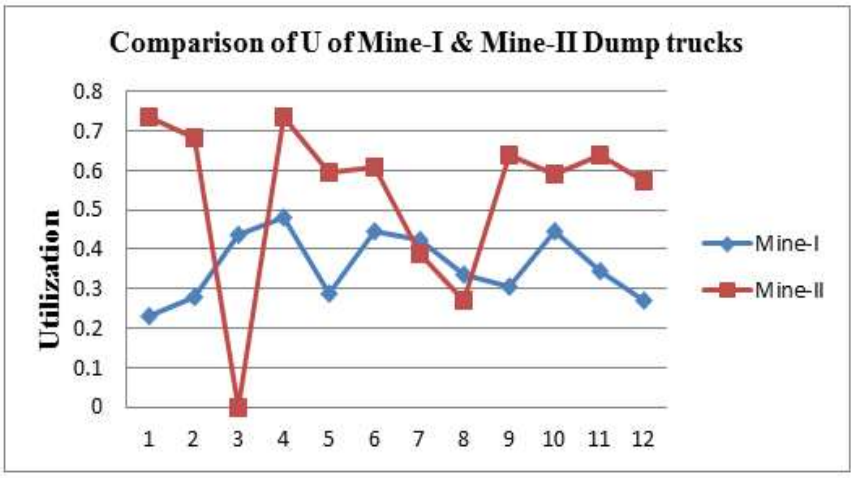

Figure 6.6 (b) Comparison of U of Mine-I & Mine-II dump trucks

Month-wise availability, utilization for the case studied Mine-I and Mine-II dump trucks have been plotted in Figures 6.6 (a) and Figure 6.6 (b) respectively. From the above Figure 6.6 (a), it is clear that availability of Mine-I dump trucks is better than Mine-II dump trucks while Figure 6.6 (b) displays utilization of Mine-II dump trucks is better than Mine-I dump trucks.

A further investigation of the results reveals that low utilization of Mine-I is mostly related to management issues. While collecting the data and field visit, it was

seen that mine authority as well as workers were not much disciplined. Somehow, it shows the incapability of the management for utilizing this capital intensive equipment. Idle time is the major issue for Mine-I. As per Coal India Limited guide lines, due to idle time, revenue loss of 85 ton dump trucks is equivalent to INR 139200 per hour. For Mine-II, maintenance and breakdown are the major problems rather than idle time. Therefore, Mine-II should adopt required countermeasures to improve maintenance and reduce downtime losses. Hence, it is suggestive from the present case study that there is sufficient scope to improve the performance of both the dump trucks following effective countermeasures.

Further, for improving the mining process, the transporting vehicles must be functional with the desired performance level. Based on this study, it is suggested that the management should categorize the dump trucks presently operated in the mines. The dump trucks which are under the poor, marginal and average category should be more focus on maintenance because if any dump truck gets breakdown, then it takes time for its repairing depending on the availability of the required spare parts in the store and the dump trucks which are in the marginal and good performance level should follow periodic maintenance and adopt suitable corrective measure to minimize idle time to improve utilization for achieving the target production level.

6.5 LOOPHOLE DIAGNOSIS THROUGH COMPARISON OF PERFORMANCE WITH BENCHMARK VALUE

Comparison of the performance of the dump truck with the benchmarked value helps to find the shortcomings in the system. The following section illustrates it by analyzing the performance of the dump truck D-1231 for the year 2017 and comparing it with the benchmarked values of the respective months.

Table 6.13 Comparison of A, U & OEPI of dump truck (D-1231) for the year 2017 with the Benchmarked (BM) values

Months (2017)	Present performance			Benchmark level of performance		
	A	U	OEPI	A	U	OEPI
January	0.71	0.58	0.29	0.83	0.81	0.53
February	0.57	0.64	0.26	0.86	0.85	0.52
March	0.22	0.68	0.11	0.84	0.79	0.54
April	0.56	0.77	0.30	0.79	0.78	0.51
May	0.41	0.38	0.11	0.80	0.90	0.47
June	0.57	0.71	0.29	0.83	0.85	0.50
July	0.50	0.55	0.19	0.80	0.78	0.48
August	0.39	0.49	0.14	0.84	0.78	0.50
September	0.61	0.65	0.29	0.83	0.79	0.50
October	0.53	0.55	0.21	0.89	0.76	0.49
November	0.44	0.70	0.22	0.90	0.73	0.50
December	0.49	0.69	0.24	0.85	0.79	0.50

Table 6.13 shows that in most of the cases the availability, utilization and OEPI of the dump truck (D-1231) is much below the benchmarked value. Since, availability is related to time losses due to repair and maintenance, therefore low availability of D-1231 indicates problems of unduly high failure and breakdown hours. Availability can be increased by doing right maintenance at right time and improving the sources of delays in repair and maintenance activities. There is also some room for the management to improving the utilization by following suitable management action and policy.

Hence, it is suggestive for the mining management that they should monitor the dump trucks performance periodically and if needed improvement should be done accordingly. There is not much space for improving the capacity losses hence, much

attention is not recommended for the capacity performance. On the other hand, environmental losses should also be tried to reduce as much as possible for improving the overall equipment performance indicator of the dump truck.

For improving the performance, the main key is to improve its availability and utilization. Availability is associated with the breakdown time and maintenance time while utilization is associated with idle time. Hence, for better availability, one needs the low breakdown and maintenance time and for better utilization the idle time should be as low as possible which is a planning issue and primarily tackle by the management. Other factors should also be improved so that the optimum OEPI can be achieved. Comparing the performance of the dump trucks with their benchmark values helps in diagnosing the lacunae and loopholes existing in the system which leads for providing the suggestions for improvement of the performance of the dump trucks.

Loading of dump trucks to their capacity is also an important factor to achieve high performance. Under-loading and overloading are detrimental to the operation because under-loading tends to be uneconomical and overloading causes fatigue and premature failure. Minor stoppages in journey, diesel (fuel) filling during working hours, minor repair work during shift hour and poor cycle time management i.e., waiting in the queue before serving by the shovel may contribute significantly to the performance of dump truck. In case of short travel distance between the loading point and dumping site, increasing the number of shovels may reduce the idle time. It is also suggested that diesel filling in the dump trucks should be done during shift break time which can also improve the OEPI.

6.6 RECOMMENDATIONS BASED ON CURRENT PERFORMANCE STATUS

Based on the present performance status the following recommendations may be done for performance improvement in general.

Performance status	Recommendations for the improvement of performance
Poor	This indicates an urgent requirement of change and need to take the effective remedial measures quickly for such shortcomings.
Marginal	This shows more maintenance and utilization are required for improving the existing performance level of the dump trucks.
Average	It is showing that more effort can increase the performance level. Few changes in the maintenance and utilization policy may be required for the improvement.
Moderate	Performance is satisfactory but there is also some scope for the improvement.
Good	It is an excellent performance range and it need not require any alteration in the existing maintenance and utilization processes. It is suggestive to continue the current practices.

From this research study, it is suggestive to the mining management that while purchasing the dump trucks, they should consider Group-B dump trucks because they are much better than Group–A dump trucks. Above study also indicates to the mining authority that where they should more focus on maintenance and where is scope to reduce the idle time of the dump trucks.