TREND ANALYSIS-A TOOL TO IDENTIFY THE FAILURE & RUN MODE IN PUBLIC TRANSPORT BUSES

M. Krishna[1] , M. Pradeep Kumar[2] , Dr. N.V.S. Raju[3]
[1]Research Scholar, JNTUH Kukatpally & Assistant Professor, Matrusri Engg. College, Hyderabad, TS - India
[2]Research Scholar, JNTUH Kukatpally, Hyderabad & Assistant Professor, KITS(s), Karimnagar, TS - India
[3]Professor of Mechanical Engineering, JNTUH College of Engineering, Jagtial, TS - India

Abstract: The availability of a system, machine or equipment for production or service is the key parameter to improve the productivity of any organization. The failures cannot be avoided completely but can be reduced through proper maintenance programme which can be developed if one can predict the occurrence and mode of failure in advance. Hence, it is the responsibility of managers to keep track of their machines or equipment and make available for maximum run hours with minimum failures. This will also help them in improving the reliability of the machines/equipment. This study is taken up to identify the failure and run modes of TSRTC buses to improve the availability and the customer satisfaction. The data regarding the bus failures and run hours for the period of 32 months has been collected and trend is analysed using graphical methods and also tested for presence of correlation.

Index Terms **- Trend, Failure mode, Availability, Time between failures (TBF), CTBF, Run Time**

I. INTRODUCTION

The Public Transport Corporations run by the state government are playing a vital role in serving the public for their day to day transportation needs i.e. for going to schools/ colleges, offices and on business works. The major part of the country's economy is from the transport systems like airways, railways, metro rail, roadways, waterways etc. They also created employment to many people directly and indirectly. Private buses, taxis, self-owned cars and auto- rickshaws are now competing with the state run public transport systems which have become threat to their existence. In the context of the competition, it is must that the state run transport operators should be available for failure free service and gain the confidence of customers with safe and satisfactory service.

The failure control of buses or equipment is the challenging task of the Managers of any organization. It is very much essential to maintain the good condition of the buses or equipment in order to provide the failure free service in the field. The maintenance programs to make the system available are of great significance due to a competition and overall operating costs. The performance of system depends on maintenance schedules, working conditions/ environment, technical skills of operators, etc. When the failures of system are low, the efficiency of organization improves and vice versa. So efforts are always needed to reduce the failure rate of the systems.

The failure of systems or equipment is unavoidable but cann be minimized with effective maintenance schedules, which can be designed only if one can predict or assess the occurrence of failure. This can be done by close monitoring of trends of failures. This trend analysis can be used to judge the life cycle characteristics of systems maintenance schedules, replacement analysis and also for designing the reliability of the system.

This study is carried out at one of the bus depots (Uppal) of TSRTC to evaluate the failure and run patterns. The aim of this paper is to investigate and identify whether the buses are deteriorating or improving based on the past run and failure data of buses.

II. OBJECTIVES OF THE STUDTY

The objectives of the present study are as follows

- To investigate failure and run patterns of buses by collecting and analyzing the data.
- To suggest a suitable maintenance program for maximising run hours.
- To improve the availability and reliability of buses.

III. FAILURE AND FAILURE PATTERNS

The Failure is the inability of a system or equipment to perform the specified function under given conditions. It can be non conformance to some predefined performance.

Failures can be as follows:

a) Based on time/age of equipment: (i) Early failures at infant stage (ii) Random failures or rare event failure (iii) Old age or wear out failures b)Based on volume of failure: (i) Small failures (ii) Minor failures (iii) Major failures (iv) Catastrophic failures

c) Based on mode of failure: (i)Sudden failures (ii) Progressive failures (iii) Retrogressive failure (iv) Gradual failures.

Failure Patterns: All systems irrespective of whether they are mechanical, Electrical etc are assumed to behave in the same manner. with reference to failure that occur, they will have any one of these three behaviours: (i) Rate of failure is decreasing (DFR) i.e. The condition of system is improving (ii) Rate of failure is constant (CFR) The condition of system may or may not be consistent but it gives the average output required.(iii) Rate of failure is increasing (IFR) i.e. The condition of system is deteriorating.

IV. TREND ANALYSIS

The objective of Trend analysis is to understand whether the system is improving or deteriorating which can be done by analyzing the past failure data.

Trend can be three types: (i) Positive trend (ii) Negative trend and (iii) No trend

(i) Positive trend:- his is due to New or infant stage of system or can be due to effective maintenance program. It implies that the system is improving with the time.

(ii) Negative trend:-This is due to frequent or long failures. It can be due to old age or worn out parts. It implies that the system is deteriorating with the time. This trend affects the productivity.

(iii) No trend: This shows the failure times or neither increasing nor decreasing. It means the system is experiencing constant failure rate. It implies that the failure behaviour if independent of the time.

Methods of Trend Analysis: There are two methods of testing the trend 1.Graphical methods for trend setting (a) Cumulative plot Test (b) Eye Ball analysis 2. Analytical trend test: (a) Laplace Test (b) MIL-HDPK-189Test

V. METHODOLOGY

In this paper, the following methods are used to test the trend:

a. Cumulative plot Test: It it tested by plotting the cumulative TBF(time between failures) against the Cumulative number of failures. The interpretations are made as follows: (i) if the derived curve is concave upward, it implies that the TBF's are becoming shorter and shorter which means the system is deteriorating.

(ii) If the derived curve is concave downward, it implies that the TBF's are longer which means the system is improving.

(i) If the derived curve is linear, it implies that there is no trend, which means the system is to be further analysed by statistical distributions.

b. Eye Ball Analysis: Eye are passed through chronological TBFs and search is done to know if there is any r increase or decrease of failures. If TBFs show increasing trend towards end, then it indicates decreasing failure rate.

Alternatively, by tabulating the cumulative frequency and divide total period into equal groups(class interval) of 5-10. If increasing failure is observed for each period, it indicates increasing failure rate and so on.

c. Test for presence of serial Correlation: It can be tested by plotting i^{th} TBF against $(i-1)^{th}$ TBF and the interpretations are made as follows: (i) if the plotted points scattered randomly without any pattern, it is interpreted that the TBF's are free from serial correlation (ii) if pattern exists, then it reveals serial correlation, then the TBF's are plotted at greater lags to search for it.

d. Analysis with Karl Pearson's coefficient of Correlation test: This is tested with i^{th} TBF v/s $(i-1)^{th}$ TBF and i^{th} TBF v/s $(i-2)^{th}$ TBF and so on. The degree of association can be interpreted with coefficient of correlation (r) which ranges from -1 to +1 via zero. (i) Close to -1 is negative association i.e. increase in first quantity induces the decrease in second quantity (ii) Close to +1 is positive association i.e. increase in first quantity induces the increase in second quantity (Proportional) (iii) Close to zero indicates poor correlation that is, both the quantities are independent.

VI. DATA COLLECTION AND ANALYSIS

The data is collected from the Uppal depot (Hyderabad) of TSRTC. The depot plies an average of 120 buses everyday in two shifts (8 hrs/shift). The data (i.e. TBF, no. o f breakdowns, late supplies, frequency of failures, total breakdown hours, total run hours, Total kilometres lost, etc) is gathered from Daily register, Breakdown register, Cancellation register and personal discussions with depot officials. The data was collected for the period of April 2015 to Nov 2017 (i.e. for 32 months) and is tabulated (Tables1&2) for further analysis and evaluation.

Table1: **Data Collection – MONTH wise on No. of break downs, late supply etc.(April 2015- Nov 2017)**

S.no	Month & Year	No of Break downs	Cum breakdowns	B.D.Kilo Meters Lost	No of Late Supplys	L.S.Kilo Meters Lost	Total Kilo Meters lost	Schduled Kilometers	Operated kilometers
1	Apr-15	20	20	23-3	10	450	2905	1166497	1013472
2	May-15	13	33	1775	10	700	2475	899365	802358
3	Jun-15	19	52	1820	14	891	2711	1145409	1020756
4	Jul-15	18	70	1445	12	667	2112	1154259	1146254
5	Aug-15	13	83	1623	7	837	2460	1130908	1051334
6	Sep-15	22	105	1909	16	2640	4549	1098030	950950
7	Oct-15	17	122	1915	14	1666	3581	1010442	1028811
8	Nov-15	25	147	1861	16	1026	2887	1133328	1028728
9	Dec-15	19	166	1413	16	1385	2567	1168538	1071061
10	Jan-16	31	197	2093	13	807	2900	1222163	1033217
11	Feb-16	19	216	1301	13	530	1831	1143368	981388

12	Mar-16	20	236	486	14	773	2259	1237663	996490
13	Apr-16	18	254	1378	13	817	2195	1185412	956374
14	May-16	18	272	1216	15	698	1914	1229756	998786
15	Jun-16	27	299	1465	15	922	2387	1187939	953773
16	Jul-16	12	311	2076	12	795	2871	1202917	951265
17	Aug-16	27	338	1431	5	371	1802	1219599	995042
18	Sep-16	26	364	1563	2	315	1878	1166247	821279
19	Oct-16	27	391	2203	3	281	2484	1145472	888459
20	Nov-16	32	423	2153	2	62	2215	1158852	888003
21	Dec-16	28	451	1721	4	211	1932	1192365	950303
22	Jan-17	23	474	1325	1	30	1355	1163792	960111
23	Feb-17	30	504	1404	6	815	2219	1077928	955200
24	Mar-17	30	534	1656	11	402	2038	1185532	956374
25	Apr-17	23	557	1638	8	474	2112	1131455	895667
26	May-17	20	577	1248	8	244	1492	1174320	947960
27	Jun-17	10	587	645	5	426	1071	1148920	935136
28	Jul-17	12	599	1115	3	172	1287	1234589	979559
29	Aug-17	12	611	972	0	0	1149	1217548	1002034
30	Sep-17	15	626	901	1	177	901	1153038	924722
31	Oct-17	13	639	964	0	0	964	1151833	929080
32	Nov-17	18	657	855	0	0	855	1145278	945900

Table 2: Daily data from 01.04.2017 to 30.09.2017(6 months)

S. No of failures	Date of Failure	TBF(Hrs)	CTBF(Hrs)	Availabl e (120*2*8 hrs)=1920 hrs/day	Cumulati ve Operation Hrs
0	0	0	0	0	
1	01-04-17	6	6	1920	1914
2	01-04-17	14	20	1920	1900
3	07-04-17	90	110	13440	13330
4	08-04-17	14	124	15360	15236
5	13-04-17	83	207	24960	24753
6	16-04-17	44	251	30720	30469
7	22-04-17	65	316	42240	41924
8	25-04-17	50	366	48000	47634
9	29-04-17	68	434	55680	55246
10	03-05-17	52	486	63360	62874
11	06-05-17	50	536	69120	68584
12	13-05-17	117	653	82560	81907
13	17-05-17	54	707	90240	89533
14	18-05-17	24	731	92160	91429
15	30-05-17	203	934	115200	114266
16	01-06-17	21	955	117120	116165
17	01-06-17	4	959	117120	116161
18	13-06-17	212	1171	140160	138989
19	16-06-17	55	1226	145920	144694
20	16-06-17	1	1227	145920	144693
21	17-06-17	20	1247	147840	146593

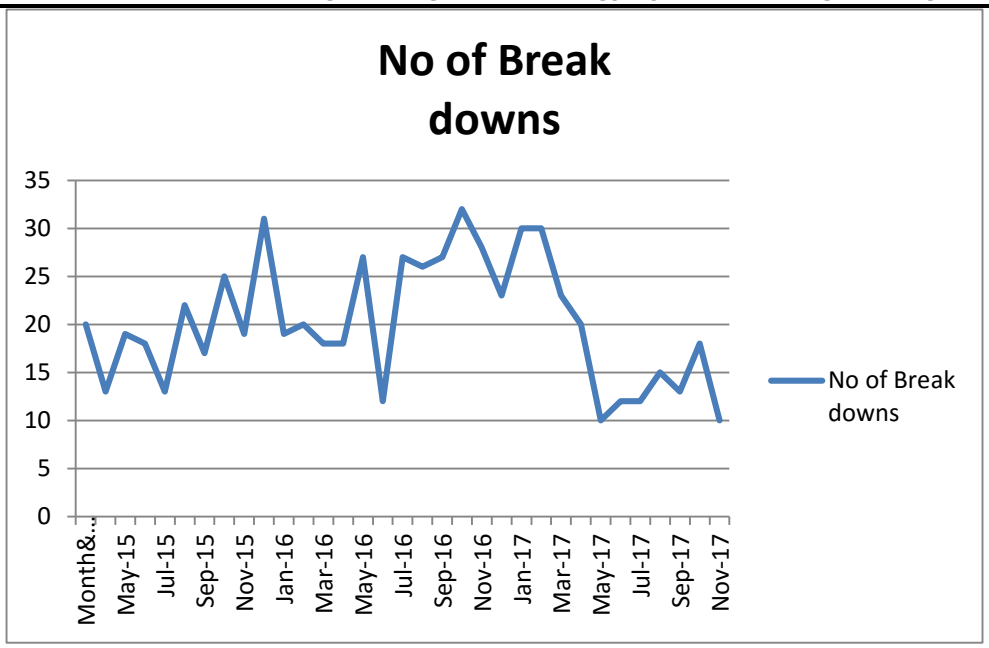
22	21-06-17	68	1315	155520	154205
23	21-06-17	1	1316	155120	153804
24	28-06-17	112	1428	168960	167532
25	29-06-17	21	1449	170880	169431
26	01-07-17	36	1485	174720	173235
27	02-07-17	15	1500	176640	175140
28	09-07-17	154	1654	190080	188426
29	15-07-17	97	1751	201600	199849
30	23-07-17	130	1881	216960	215079
31	25-07-17	134	2015	220800	218785
32	04-08-17	44	2059	238080	236021
33	07-08-17	54	2113	243840	241727
34	11-08-17	203	2316	251520	249204
35	24-08-17	3	2319	276480	274161
36	24-08-17	32	2351	276480	274129
37	26-08-17	73	2424	280320	277896
38	30-08-17	83	2507	288000	285493
39	05-09-17	50	2557	297600	295043
40	09-09-17	108	2665	305280	302615
41	16-09-17	114	2779	318720	315941
42	23-09-17	22	2801	332160	329359
43	24-09-17	80	2881	334080	331199

Table3: Year wise failures

Month & Year	No of Break downs	Kilo Meters Lost
2015-16	236	199840
201616-17	298	195910
17-18 (upto Nov.2017)	123	87745

Table 4:_ Cumulative frequencies (Class wise)

Class Interval (from Table2)	Period(group)	Cumulative.Failure in hours
1-6	1	251
7-12	2	402
13-18	3	518
19-24	4	257
25-30	5	453
31-36	6	470
37-42	7	450

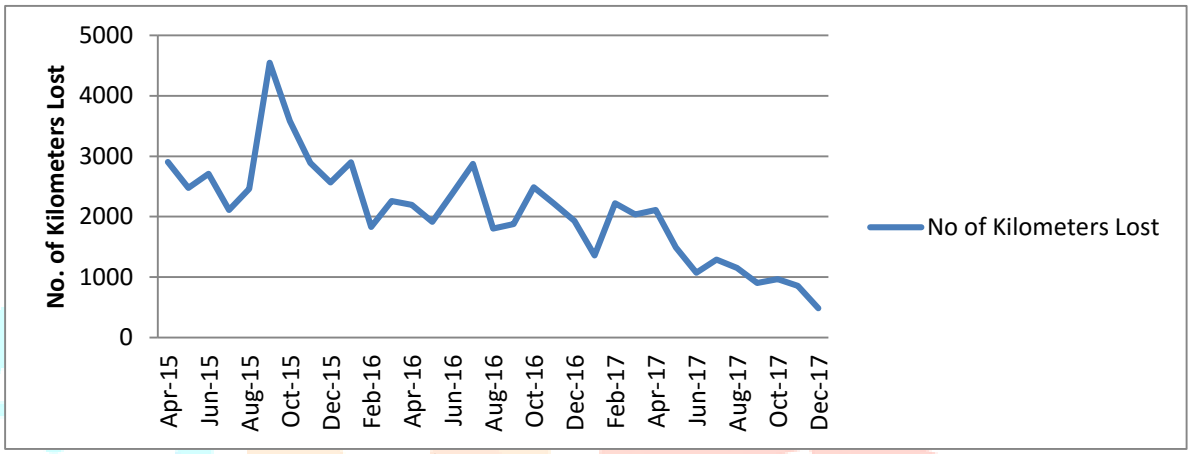


Graph 1: Month wise Breakdowns (April 2015 to Nov 2017)

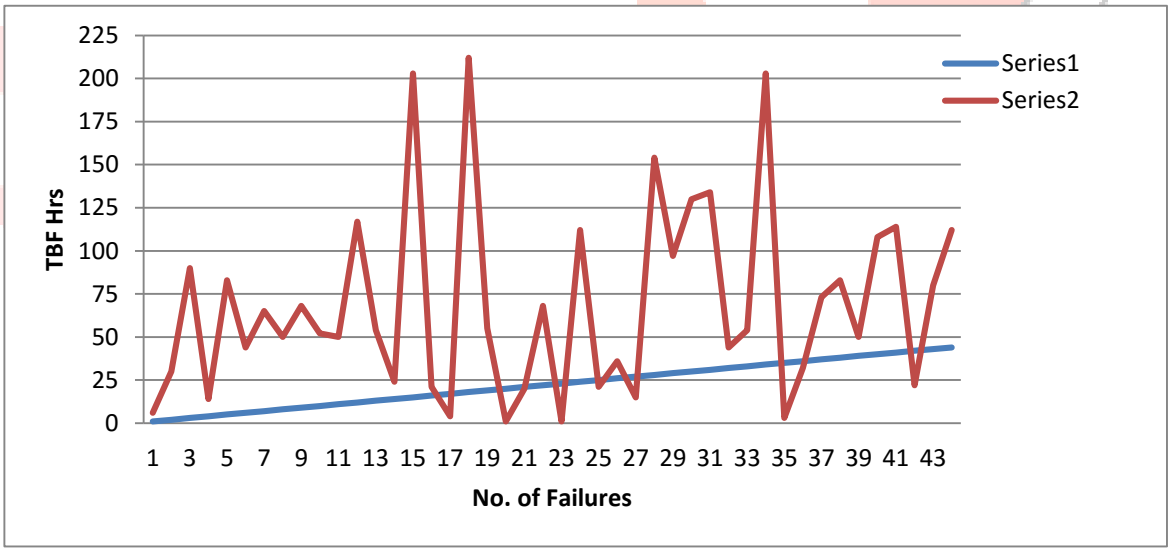
Table 5: Karl Pearson's Coefficient of Correlation and Serial correlation.

SNO	TBF(i)	X=i-68	i-1	y=(i-1)-67	X**2	Y**2	X*Y
0	0	0			0	0	0
1	6	-62	0	-67	3844	4489	4154
2	30	-38	6	-61	1444	3721	2318
3	90	22	30	-37	484	1369	-814
4	14	-54	90	23	2916	529	-1242
5	83	15	14	-53	225	2809	-795
6	44	-24	83	16	576	256	-384
7	65	-3	44	-23	9	529	69
8	50	-18	65	-2	324	4	36
9	68	0	50	-17	0	289	0
10	52	-16	68	1	256	1	-16
11	50	-18	52	-15	324	225	270
12	117	49	50	-17	2401	289	-833
13	54	-14	117	50	196	2500	-700
14	24	-44	54	-13	1936	169	572
15	203	135	24	-43	18225	1849	-5805
16	21	-47	203	136	2209	18496	-6392
17	4	-64	21	-46	4096	2116	2944
18	212	144	4	-63	20736	3969	-9072
19	55	-13	212	145	169	21025	-1885
20	1	-67	55	-12	4489	144	804
21	20	-48	1	-66	2304	4356	3168
22	68	0	20	-47	0	2209	0
23	1	-67	68	1	4489	1	-67
24	112	44	1	-66	1936	4356	-2904
25	21	-47	112	45	2209	2025	-2115
26	36	-32	21	-46	1024	2116	1472
27	15	-53	36	-31	2809	961	1643
28	154	86	15	-52	7396	2704	-4472
29	97	29	154	87	841	7569	2523
30	130	62	97	30	3844	900	1860
31	134	66	130	63	4356	3969	4158
32	44	-24	134	67	576	4489	-1608
33	54	-14	44	-23	196	529	322

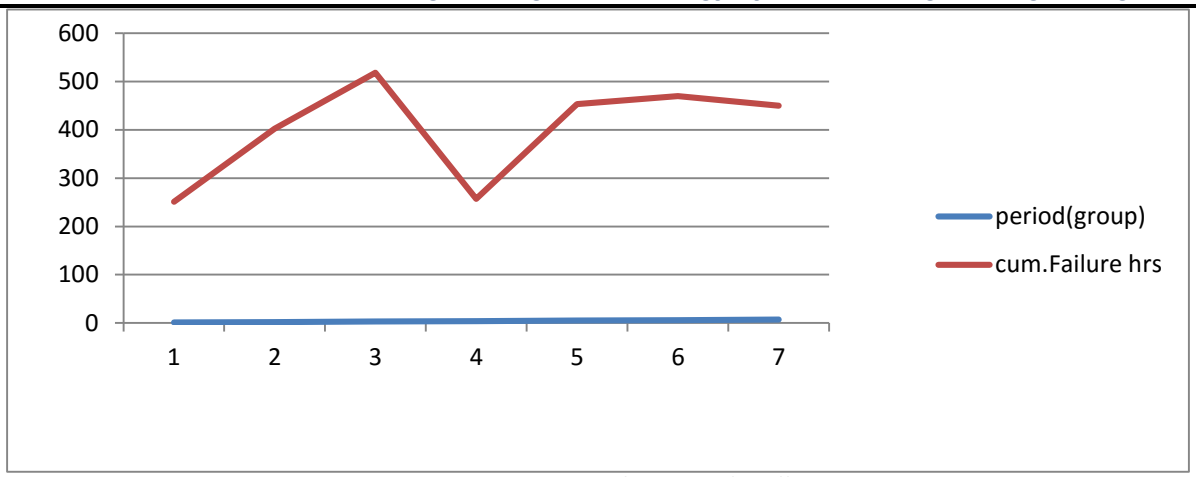
34	203	135	54	-13	18225	169	-1755
35	3	-65	203	136	4225	18496	-8840
36	32	-36	3	-64	1296	4096	2304
37	73	5	32	-35	25	1225	-175
38	83	15	73	6	225	36	90
39	50	-18	83	16	324	256	-288
40	108	40	50	-17	1600	289	-680
41	114	46	108	41	2116	1681	1886
42	22	-46	114	47	2116	2209	-2162
43	80	12	22	-45	144	2025	-540
44	112	44	80	13	1936	169	572
Sum	3009		2897		129071	131613	-22379



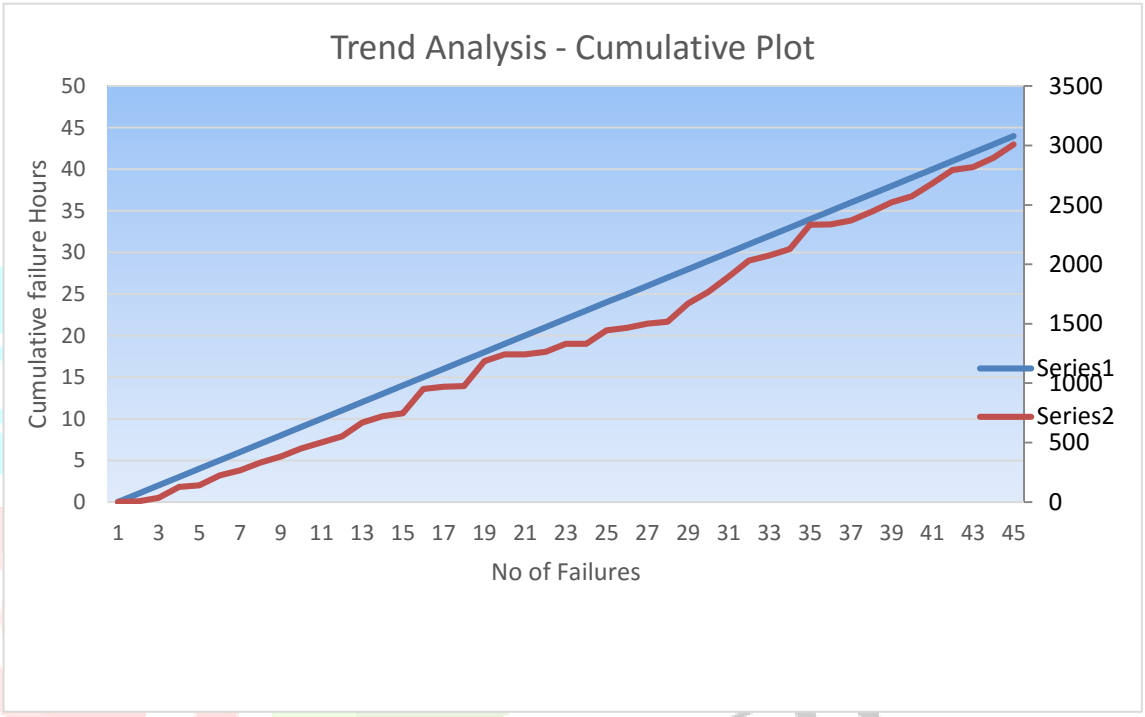
Graph2: Plot showing the number of breakdowns and kilometres lost during the years 2015 to 2018



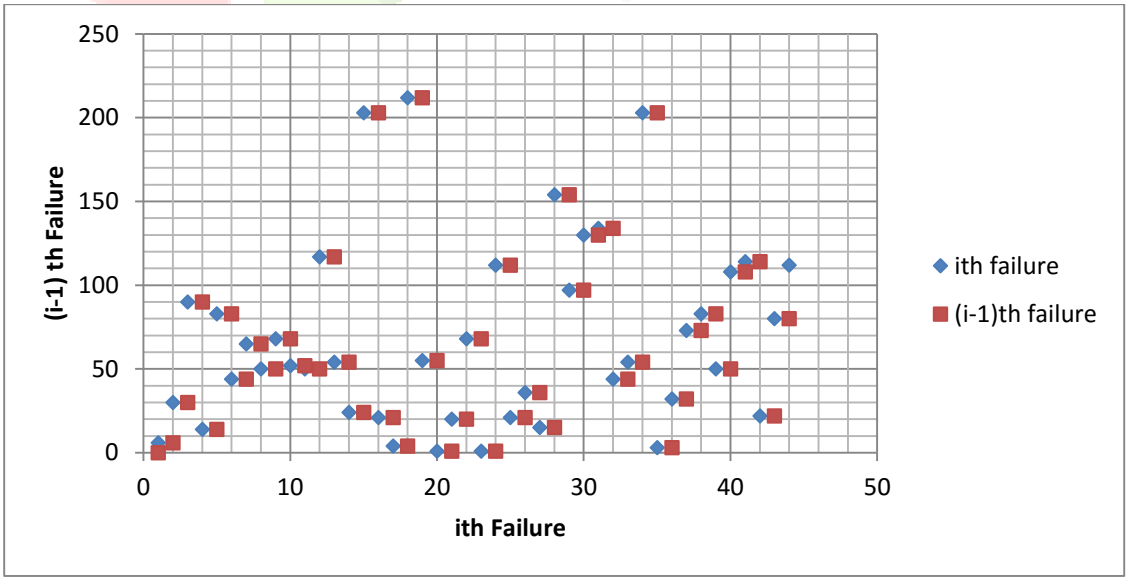
Graph 3a: Plot showing the number of failures vs Time between failures



Graph 3b: Plot showing cumulative frequencies for different groups



Graph 4: plot showing the number of failures vs cumulative failures



Graph 5: Plot showing the trend between i^{th} failure and $(i-1)^{th}$ failure

VII. RESULTS AND DISCUSSIONS

The data from table 1 is plotted between number of failures per month during the year April 2015 to November 2017. It can be obserevd that the failure rate almost remained the same during this period. It is evident from graph 2 that the number of kilometers lost has decreased although the failure rate increased. This may be due to the availabilty of spare buses at the depot.

From the tabulated data in Table 1 and Table 2 , the following factots are evaluated. The frequency of breakdown is 3 per 10,000 kms and the bus utilization is 96 percent. From Eye Ball Analysis graphs 3(a) and 3 (b), it is observed that TBF's are increasing for the first three periods which indicates a decrease in failure rate. Later there is a decrease in TBF's showing an increase in failure rate.

The number of failures vs cumulative failure hours is plotted for trend analysis is shown in Graph 4. The curve is concave downward indicating that the availability of buses is increasing.

The scatter plot i.e. graph 5 drawn between the trend between ith falure and (i-1) th failure indicates that TBF's are scattered and hence show they are free from serial correlation.

From Table 5, coefficient of correlation ' r' is calculated as 0.17 using the following equation1. The positive value indicates close association between two successive failures.

$r = \sum(X*Y)/(\sqrt{\sum X**2 * \sum Y**2})$ ----- Eqn 1.

VIII. CONCLUSIONS

- The cumulative plot (from april2017 to Nov 2017) shows that the curve is concave downward, which indicates that the bus availability is improving. It is also evident from the fact that the failures have come down by 28% in 2017-18 compared to 2016-17.
- In spite of less failures and availability of bus hours, the operational efficiency has come down (56.85 lakh kilometers operated in 2017-18 as against 65.65 lakh kilometers in 2016-17). It is suggested that the traffic department should initiate suitable action.
- Average breakdowns are 20 per month, though the scheduled maintenance is carried out, which require more attention and focus of the maintenance department.
- The positive value of Coefficient of Correlation (r= 0.17), shows there is proportional association between two successive failures. The random scattered plot indicates that the TBFs (Time between failures) are free from serial correlation.

IX. REFERENCES

[1] Dr. N.V.S. Raju, "Plant maintenance and Reliability Engineering", Cengage Learning-2011.

[2] Wayne Nelson, "Graphical Analysis of System Repair Data", Journal of Quality Technology, USA, Vol.20, No.1, pp 24-35

[3] Wokshop manual of APSRTC(2009)

[4] E.E.Lewis, "Introduction to Reliability Engineering", John Wiley,1989.

[5] Mobley, "Reliability centered Maintenance" -2004.

[6]. Al-Najja, 1995, Mobley 2004, Lindsey & Darrin, 2000. Maintenance Theory

[7] Maintainability-Kaduna Polytechnic, 2001.

[8] D.Bose, G.Ghosh, K.Mandal, S.P.Sau, S.Kunar, Measurement and Evaluation of Reliability, Availability and Maintainability of a Diesel Locomotive Engine- International Journal of Scientific and Research Publications, Volume 3, Issue 9, September 2013 1 ISSN 2250-3153.

[9] D. R. Dolas, M.D. Jaybhaye , S. D. Deshmukh, Estimation the System Reliability using Weibull Distribution- DOI: 10.7763/IPEDR. 2014. V75. 29.

[10] R. E. Barlow, R. Campo, "Total Time on Test Process and Applications to Failure Data Analysis", *Reliability and Tree Analysis,* (Eds. Barlow, Fussel, Singapurwalla) SIAM, Philadelphia, 1975.

[11] Crow L.H, "Reliability Analysis of Complex Repairable Systems", *Reliability and Biometry*, Ed. F. Proschan and R.J. Serfling, SIAM, Philandia 1974.