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Examination of the viability of a common maintenance practice for transit mixers in ready mix concrete plants.

Dr. Gopal Mulugund[1], Dr. Reuben Buthello[2], Dr. B.J. Godboley[3], Dr. Pandharinath Ghonge[4]

[1]*Professor, St. John College of Engineering & Management, University of Mumbai, India*
[2]*Assistant Professor, St. John College of Engineering & Management, University of Mumbai, India*
[3]*Associate Professor, St. John College of Engineering & Management, University of Mumbai, India*
[4]*Associate Professor, St. John College of Engineering & Management, University of Mumbai, India*
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ABSTRACT

Owing to the rapid growth in the construction industry, ready mix concrete (RMC) plants have flourished across various cities. The special trucks called transit mixers that operate in these RMC plants are complex machines whose maintenance schedules are governed by both the number of kilometres travelled and the number of hours of operation. This has led to complications in maintenance management. A further complication is the fact that the operations of such transit mixers are dependent on the location of the RMC plant. Original Equipment Manufacturers (OEMs) of these transit mixers suggest a preventive maintenance program that is based on Scheduled Maintenance and is common to all transit mixer irrespective of their operations. This paper examines the role of the location of the RMC plant and the role of the brand of the Chassis manufacturer and the mixer manufacturer in such operations. The paper has been able to ascertain that operations of transit mixers are varied across plants and can lead to significantly different requirements in maintenance. It also sets the ground work for future work on the topic to access whether such operations affect the maintenance cost and downtime of transit mixers.

Keywords: *Construction, Operations, Maintenance, Ready Mix Concrete, Transit Mixers.*

1. Instructions

With the phenomenal growth that is being witnessed in the Indian Economy, the Construction Industry has seen tremendous growth and investments. In over 2000 years, humans have still not been able to find a cost effective replacement for Concrete and thus concrete remains one of the key ingredients to the growth story of India. Ready Mix Concrete is a heterogeneous mixture of cementatious material like cement, Flyash, granulated ground blast furnace slag, aggregate (stone), sand, water and admixtures which is manufactured at a specialized factory called a ready mix concrete plant and then supplied to the construction site through specialized trucks called Transit Mixers. The location of ready mix concrete plants in relation to their clients has been found to be varied. In some cases, ready mix concrete plants have their clientele spread across the city while in some cases plants have their clients concentrated at certain locations. Some ready mix concrete plants cater to just one client who is located very close to the plant itself. Hence depending on the location of the ready mix concrete plant in relation to their clients, transit mixers need to travel large distances to reach a client or small distances to reach a client. This has led to a unique problem which is affecting the maintenance of these Transit Mixers.

A transit mixer is complex piece of machinery. It consists of a truck chassis which has a separate engine and driveline for locomotion and a Mixer Assembly which has separate engine and hydraulic system to power the concrete mixer apparatus. The maintenance of the engine and the driveline of the truck chassis is governed by the number of kilometers driven by the transit mixer, while the maintenance of the engine and hydraulic system of the concrete mixer apparatus is governed by the number of hours of operation of a transit mixer. Here it is apparent that transit mixers which have clients located close to the ready mix concrete plants will have high hours of operation as compared to kilometers travelled and the reverse if the ready mix concrete plant is located far away from the client. This brings up challenges to the maintenance schedules prescribed by the original equipment manufacturer.

1.1. Maintenance Management

Maintenance is a complex activity which involves support from various sections of the organization as well as from agencies outside the organization and its aim is to support and maintain efficient production [2]. The Maintenance needs may defer based on the size of the Organization, availability of resources, criticality of machinery, organization culture and commitment of top management. Maintenance has changed from breakdown maintenance to preventive maintenance [3];

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as industry matured, it was realized that a holistic approach [4] to maintenance would be needed to cater to an ever increasing complex industry involving numerous machines, systems and automation. The complexity rises further when there are multiple components in an assembly and multiple assemblies in machines. The usual strategy is to replace the damaged parts so as to bring the machine to an operational state. However, what is observed is that the successful working times of such machines get shorter and shorter [5].

1.2. Problem Statement

Are transit mixers that are operating in different ready mix concrete plants experiencing significant difference in the proportion of number of kilometers of operation to number of hours of operation? What are the recommended preventive maintenance schedules that have been recommended by the original equipment manufacturer (OEM)? What is the effect of the operations of a ready mix concrete plant on the preventive maintenance schedules of a transit mixer? In this research, we intend to find the significant difference in Kms Covered, hours of operation caused due to plant location and its effect on the preventive maintenance schedules recommended by the OEM.

2. Literature Review

Transit Mixers come in different sizes to carry different capacities from 3 cum to 9 cum. However, past research has shown that there is not much difference in the efficiencies over a long period by having transit mixers of difference capacities as shown by S.L Tang and others [8]. Past research has also indicated that improper maintenance management can lead to higher risk to life of people working around such vehicles [9]. [10] The author Campbell was referred to have a better understanding of Equipment age interval, Frequency of Inspection, Optimal Resources and Economic Life Cycle of an Equipment. R.J. Ormerod [11] has described in detail the necessary steps needed to take into account in order to scientifically and exhaustively model a maintenance problem. The steps mentioned have been summarized as follows: 1. Definition of the problem under study. 2. Consideration of the required data. 3. Preparation of the data to fit into the model. 4. Benchmarking the data with other sources. 5. Analysis of the results and formulation of a suitable maintenance policy. 6. Model Utilization payoff analysis. In order to effectively devise a maintenance strategy, it is important to have the correct and accurate information about the operations of the company and the machinery under study. The study by Fraser, K. is to showcase the various maintenance models that are prevalent in the real world and this papers also attempts to bridge the gap between theory and practice by bringing attention to the various models that are currently being used in the industry with those that are not. The authors de la Hermosa González and others [13] of this article have decided to formulate a maintenance system to study or predict structural or mechanical problems in a wind tower. This is similar to transit mixers where tremendous study has been done on individual components of a truck such as the engines, the hydraulic system, the coolant system, the electrical components and various other sub-systems of a vehicle; however, very little work has been done on the transit mixer itself. Mazurkiewicz, D. [14] has demonstrated that a number of parameters that govern the performance of the belt which are belt speed, belt runoff, metal component pieces on the belt, belt temperature, belt wear can be monitored by just monitoring one parameter which has a significant correlation with the performance and reliability of the belt. In the case of transit mixers, the number of kilometers travelled and the number of hours of operation are two such parameters that has a significant correlation with the performance and reliability of the transit mixer as a whole. The Authors Abhishek Jain and others [15] have studies a total of 148 papers related to Total Productive Maintenance and have classified them in to various categories. They have used literature surveys to arrive at how maintenance has evolved over the years from simple breakdown maintenance to today's modern maintenance practices. The author Sridhar [16] has put together the process that is followed for the planned fleet maintenance of an international airport. The process is able to handle a variety of maintenance problems such as breakdown maintenance, preventive maintenance, Accident repairs. The author RAWAT, M [17] has identified that in life cycle costs, the Level of Repair (LOR) and Stock of Spare parts are the two most important aspects of any fleet maintenance. The main contribution of this paper is arriving at an optimization of both the level of repair and the spare parts stocking decisions. The author then uses weibull analysis with the help of an example to check his model.Techniques, and applications such as ANOVA to find influencing factors on the performance evaluation of assembly line balancing problem level 1 by Hu, Jan [18], Chi Test, and other statistical tools have been studied which have provided innovative ways of interpreting the results. ANOVA has also been used to analyze the difference in driving patterns between different drivers and to analyze their driving habits in the work done by Jamson as mentioned earlier. Another interesting application of ANOVA has been demonstrated where telematics data has been analyzed to get interesting insights on fleet operations by the author Said [19]. ANOVA can also be used to prove significant relationship between independent variables and dependent variable as shown in a study for the UNHCR by Gitahi [20]. A subtle understanding of Non-parametric statistics too was undertaken since a lot of real world data follow especially when the population is not large tends to be non-parametric Jean Dickinson [21].

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3. Objective of the Study

3.1. Identify the significant difference between the Kms covered by the vehicles and hours of operation due to the plant location.
3.2. Analyze the preventive maintenance schedules recommended by the chassis manufacturers and the mixer manufacturers of different OEMs.
3.3. Examine the effect of the variations of operations of a ready mix concredte plant on the preventive maintenance schedules.

4. Hypothesis Development

The following hypotheses are tested to study the above mentioned objectives:

4.1. Identify the significant difference between the Kms covered by the vehicles and hours of operation due to the plant location:
H0: There is no significant difference between the Kms covered by the vehicles and hours of operation due to the plant location
H1: There is a significant difference between the Kms covered by the vehicles and hours of operation due to the plant location
4.2. Identify the significant difference between maintenance issues arising in transit mixers across plant locations:
H0: There is no significant difference in maintenance due to the plant location
H1: There is a significant difference in maintenance due to the plant location

5. Research Methodology

5.1. Research Design:

The research design will be an Observational Study. A study and comparison of the maintenance practices involved in 8 ready mix concrete plants. The research will involve the study of various operational and maintenance activities being carried out in fleet operations in Ready Mix Concrete Plants.

5.2. Data Source (Secondary Data):
5.2.1. Most Transit Mixer contractors or owners maintain maintenance records of their fleets. These records include maintenance costs incurred, duration between service intervals, duration of service, cost involved in the maintenance of the transit mixers.
5.2.2. Ready Mix Concrete plants normally maintain records of plant and vehicle operation. Typically, Transit Mixer operational timings, uptime details, records of breakdowns or corrective maintenance are noted by the plant managers. These historical vehicle maintenance records will be gathered from fleet operators and Ready Mix Concrete Plants.

5.3. Population Characteristics:

There are approximately 60 ready mix concrete plants operating within the region of Mumbai, with an average of 10 Transit mixers operating in each plant. This brings the approximate number of transit mixers in Mumbai to 600.

5.4. Sample Size:

11255 entries over which a bulk of our hypothesis has been conducted. Using Cochran's sample size formula the sample size was calculated and is found to be too small as compared to the data that has been collected. Hence we shall go by the total data collected in the study.

6. Data Analysis
6.1. A descriptive analysis of the data collected has brought out the following information:
6.1.1. Plant Information:

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Plant Name	Frequency	Average of Kms Covered	Std-dev of Kms Covered	Average of No of hours	Std-dev of No of hours	Ratio of Kms to Hrs of Operation	Level
ACC Deonar	482	24.41	10.08	3.44	1.93	7.10	High
Cemix Beton	1836	16.09	12.31	3.64	2.38	4.42	Medium
Cemix Concrete	391	6.04	9.12	2.64	2.17	2.29	Low
Godrej Boyce	1088	17.33	10.4	3.89	2.42	4.46	Medium
Lafarge Kurla	2167	13.34	12.19	3.29	2.26	4.05	Medium
Lafarge Wadala	1641	10.31	12.12	2.97	1.98	3.47	Low
RMC Sakinaka	2516	16.46	10.73	3.16	1.82	5.21	High
RMC Wadala	860	17.72	11.78	3.35	2.17	5.29	High

Table 1. Descriptive Data on Plant Locations

System	Low	Mid	High	Total
Axle	13	33	35	81
Brake	19	75	51	145
Chassis Body	35	125	109	269
Clutch	19	85	51	155
Electrical	37	100	108	245
Engine	77	224	162	463
General checkup	10	23	19	52
Handi	53	94	73	220
Steering	0	8	6	14
Suspension	15	38	20	73
Transmission	11	28	22	61

The above table clearly shows how transit mixers in ACC Deonar operate far more kms on an average as compared to their counterparts from other ready mix concrete plants like Cemix Concrete which has the lowest Kms to Hrs of Operation ratio. The table also clearly displays there is no industry average that can be used as the basis for setting up a median for measuring individual companies. Hence it is imperative that maintenance policies be crafted to suit the operations of a particular plant location. In order to analyze this further, let us divide the plant locations in three categories viz. Low, Medium & High. Let Low level represent RMC plants which have a Km/Hr ratio of less than 4. A Med Level having km/Hr ratio of between 4 and 5 and all the plants with an average km/hr ratio of above 5 be categorized as High Level.
Using this matrix we can then analyze the maintenance of the various transit mixers across the three categories of RMC plants. The details of the same has been tabulated in Table. 6.1.2.

Maintenance Failures Across Systems:
As discussed earlier, the transit mixer can be broadly segregated in to the locomotive part which is the Chassis and the Concrete Mixer part which is the MIXER or the HANDI. The locomotive part of the transit mixer has

various sub systems which are Axle, Brake, Chassisbody, Clutch, Electrical, Engine, General Checkup, Steering, Suspension & Transmission. From the maintenance data collected, we can assign the maintenance failures into these various categories and thus we can compare the maintenance failures and across various ready mix concrete plants.

6.1.2. Instances of Maintenance Failures across Plant Locations

Interpretation:

What has been observed in the analysis is that nearly 86% of the maintenance Failures in Mid and High RMC plants i.e. RMC plants with high/mid km/hr ratio occur in the Locomotive part of the Transit Mixer i.e. the Chassis. The balance 14%

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of the failures are in the Mixer component of the Transit Mixer. These figure change drastically in RMC plants with Low km/hr ration falling to 76% in the Chassis Systems and 24% in the Mixer Systems. This clearly indicates that the failure rates for different components in the Ready Mix Transit Mixer is dependent on the km/hr ratio that is operated by the RMC plants.

6.1.3. Mixer Information:

Table 2. Descriptive Data on Mixer Manufacturers

Mixer Manufacturer	Frequency	Average of Kms Covered	StdDev of Kms Covered	Average of No of hours Final	StdDev of No of hours Final
GREAVES	5077	13.65	12.26	3.14	2.04
LIEBHERR	1491	19.19	11.17	4.07	2.52
SCHWING SETTER	3918	15.54	11.70	3.29	2.13

Mixers belonging to Schwing Stetter and Greaves form a large chunk of transit mixers in the sample considered. Out of 11255 RMC plant trips, maximum were covered by Greaves mixer manufacturer i.e. 5083 and minimum by Liebherr mixer manufacturer i.e. 1500. Out of 100% RMC plant trips, maximum were by Greaves i.e. 45% mixer manufacturer available and minimum by Liebherr i.e. 13% mixer manufacturer were available.

6.1.4. Chassis Information:

Table 3. Descriptive Data on Chassis Manufacturers

Chassis Manufacturer	Frequency	Average of Kms Covered	Std-dev of Kms Covered	Average of No of hours Final	Std-dev of No of hours Final
AMW	664	24.18	10.20	3.40	1.84
ASHOK LEYLAND	9957	14.72	11.85	3.34	2.18
TATA	468	8.66	11.39	2.77	2.12

Chassis belonging to Ashok Leyland formed a large chunk of transit mixers in the sample considered. Out of 11255 RMC plant operations, maximum were undertaken through Ashok Leyland's chassis i.e. 9978 trips through this chassis manufacturer available and minimum was done through the chassis manufacturer Tata i.e. 568 trips; i.e. of 100% of the sample size, Ashok Leyland's chassis had 89% of the trips followed by AMW and then by Tata with 4% in RMC plants across Mumbai.

6.2. Inferential data analysis on the data collected:

6.2.1. To identify the significant difference in the Kms covered by the vehicles, hours of operation with respect to plant location.

Table 4. Anova Table for Plant Location

		Sum of Squares	df	F	Sig.
Kms Covered	Between Groups	91531.403	6	114.339	.000

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	Within Groups	1399858.666	10492		
	Total	1491390.069	10498		
No of hours Final	Between Groups	998.253	6	36.100	.000
	Within Groups	48354.700	10492		
	Total	49352.953	10498		

At 95% significance level, p value i.e. 0.000 is less than α i.e. 0.05 ($p < \alpha$) so we reject the null hypothesis and accept the alternative hypothesis that there is a significant difference in the Kms covered by the vehicles, hours of operation due to plant location.

6.2.2. To identify the significant difference in the Kms covered by the vehicles, hours of operation with respect to mixer manufacturer.
The Anova test was conducted to analyse the effect on mixer manufacturers on the kms covered by a transit mixer. The data for the same has been summarized as follows:

Table 5. Anova Table for Mixer manufacturer

		Sum of Squares	df	F	Sig.
Kms Covered	Between Groups	39447.423	2	139.961	0
	Within Groups	1462079.718	10375		
	Total	1501527.141	10377		
No of hours Final	Between Groups	1174.021	2	127.966	0
	Within Groups	47592.42	10375		
	Total	48766.442	10377		

At 95% significance level, p value i.e. 0.000 is less than α i.e. 0.05 ($p < \alpha$) so we reject the null hypothesis and accept the alternative hypothesis that there is a significant difference in the Kms covered by the vehicles, hours of operation with respect to mixer manufacturer.

6.2.3. To identify the significant difference in the Kms covered by the vehicles, hours of operation with respect to chassis manufacturer.
The Anova Test was conducted to analyse the effect on chassis manufacturers on the kms covered by a transit mixer. The data for the same has been summarized as follows:

Table 6. Anova Table for chassis manufacturer

		Sum of Squares	df	F	Sig.
Kms Covered	Between Groups	75413.875	2	274.274	0.000
	Within Groups	1509246.146	10978		
	Total	1584660.021	10980		

No of hours Final	Between Groups	149.419	2	16.086	0.000
	Within Groups	50987.457	10978		
	Total	51136.876	10980		

At 95% significance level, p value i.e. 0.000 is less than α i.e. 0.05 ($p < \alpha$) so we reject null hypothesis and we accept the alternative hypothesis. So we can conclude that there is a significant relationship between chassis manufacturers and Kms covered.

7. Conclusion

The analysis of the data has clearly indicated that the location of the ready mix concrete plant, the type of mixer manufacturer and the chassis manufacturer all have a profound effect on the number of kilometers covered by the transit mixer and the number of hours of operation of a transit mixer. This in turn has a major bearing on the average kms/Hr ratio operated by Transit mixers in the respective RMC plants. Hence Transit Mixers operating in High and Medium km/Hr ratio plants will experience tremendous amount of strain in the chassis driveline while those operating in Low km/Hr ratio plants will experience a strain in the Mixer Components. It is evidently clear that a preventive or scheduled maintenance system will have to be customized for each ready mix concrete plant since the operations and challenges posed by them are different. This paper has therefore achieved its goal in identifying that there is a problem which needs further consideration and simple maintenance schedules specified by the original equipment manufacturers are simply not enough to solve complex maintenance problems.

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