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Improve Maintenance Performance Monitoring Through Analysis of Work Order Historical Data – A Case Study

Vijayanand M
Samconssp, India

***Abstract*– Management periodically reviews maintenance performance. For this, maintenance work order data is considered. This paper discusses about inferring from existing maintenance work order data. These inferences are made using observations, simple statistics and conducting root cause analysis**

***Keywords* – maintenance work orders; statistics; work order data review; root cause analysis; forecasting**

I. INTRODUCTION

A management review of plant maintenance performance is common in most process industries. This is done at various levels and in varying detail. The size of the plant, the number of plants in a complex, the size of the maintenance department, and levels of management may vary from organization to organization. The aspects of maintenance reviewed, the sources for data collection, data collected, quality of data, data analyzed and performance parameters monitored may vary from organization to organization, plant to plant, level of management monitoring the performance, the person reviewing the performance and so on.

Unscheduled maintenance, maintenance crew moving from one emergency to another, budgetary constraints, and reactive maintenance are common in process plant maintenance. Introducing a systematic approach and analysis into the maintenance function can help alleviate these problems.

This paper considers WO data from the mechanical maintenance discipline in two identical plants (P1 and P2) in a medium-sized chemical industry. These two plants are similar in terms of product, technology, layout, maintenance team, capacity, and service age. Each plant operates continuously and produces 1500 MT/day. Management reviews mechanical maintenance performance every month. The head of the maintenance discipline reviews the performance. The complex uses commercially available software to process maintenance WOs. Statistics is hardly used in this organization for analyzing data.

The existing monitoring of maintenance performance exhibits certain deficiencies like reviewing monthly data without adequate consideration of established performance norms, absence of a formalized plan of action, insufficiently defined responsibilities, reviewing the same point over and again with no progress made, and lack of tangible progress resulting from these reviews. Systematic methods are not used in assimilating, organizing and inferring from data. Data is presented for review without any analysis done on it.

Many process organizations refrain from investing in expensive software packages for data analysis. Furthermore, a majority of maintenance and planning professionals may lack proficiency in complex data analysis methods and procedures. This paper, a case study, presents ways to analyze maintenance WO data using simple statistical options in Microsoft Excel and through observation. Then inferences (suitable for running a maintenance discipline in an industry and not to be seen from a purely statistical standpoint) are drawn. These additional inferences will help monitor and improve the performance of the maintenance department. More inferences than those presented here may be made from existing data. Data for 5 months is available from each plant, and the same is analyzed. The available data is such that the time between two sets of successive data is uneven.

TABLE I. WO CATEGORIES

WO designation	WO type description	WO type sub-classification (Activities carried out)
T1	One-time	• Refurbishment • Miscellaneous jobs • Workshop order • Project related • Hot work • Corrective maintenance • Consumables reservation • Services • Overhauling
T2	Preventive maintenance	• Calibration • Inspection • Overhauling • Replacement • PM of rotating equipment
T4	Refurbishment, Workshop	• Machining activity • Refurbishment • Overhauling • Calibration
M3	Management of change	• Material • Service
M8	Miscellaneous activity, consumables reservation, service bills	• Service • Material

II. STUDY METHODOLOGY

The following is the methodology for this study:

1. Identification of plants for study
2. Identification of existing practices for reviewing
3. Collecting historical maintenance WO data (currently being used for monitoring and reviewing)
4. Examining this data and making further inferences
5. Proposing additional aspects for monitoring and reviewing

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III. DATA COLLECTION

The following data and values are collected:

- Types of maintenance WOs
- Description and content of WOs
- Number of WOs in a month
- Cost (WII) for WOs open in a month
- Production rates of both plants

IV. OBSERVATIONS AND ANALYSIS

1. Work hours and the number of the contractor workforce used were not maintained in most of the WOs. Analysis of utilization of existing contractor workforce is not done or reviewed. The unit cost rate of service for the contractor workforce is very low. With the size and revenue output of the organization, contractor costs were negligible and hence there is little focus on contractor workforce costs. Contractors perform activities like rigging, preventive maintenance jobs, scaffolding, and welding.

2. Task descriptions in most of the WOs do not convey the maintenance issue correctly or in needed detail. Standardization of keywords in the WO description does not currently exist. This inconsistency complicates the analysis of work orders.

3. Details about the organization's workforce numbers and services that they rendered against a WO were not captured. Only arbitrary numbers were entered in the WOs.

4. Parts like shafts, and sleeves for mechanical seals were machined at a local workshop. However, drawings with proper fits were not available.

5. There were many duplicate T4 type WO (without WII) and T1 type orders (without WII) in both plants. This increased the number of WO but did not affect the total WII. This indicates a lack of systematic job planning activity and gaps in communication within the maintenance department.

6. Two different T1 type orders were made on the same day for the same equipment, and there were no multiple breakdowns of that equipment.

7. Many WOs for corrective repairs, where material was used, do not have costs associated with them in the WO.

8. Root cause analysis has a separate process linked to the WO system. In this process, whenever a WO is marked with certain criteria, an RCA activity is automatically generated against the WO. There were cases when another WO was generated (as initial WOs were raised without entering all the needed data and so an RCA was not triggered) to carry out an RCA and upload the analysis report. Not following the process increases the work of personnel and also lowers the efficiency of the RCA work process.

9. In the 5^{th} month, the WII was negative in the P2 plant as no WOs requiring costly spares were raised, and there was a return of excessively withdrawn spares (from earlier months) back to stores. Material return is treated as negative WII.

10. The T1 type work orders with WII were checked to see if there is potential to reduce WII. There was a case where three WOs were raised against the failure of three identical units, wherein a similar component for the three units was changed, in plant P1. No RCA was found. By conducting a proper RCA for these failures, future failures may be eliminated, thus reducing the cost of maintenance (and thus WII in any week).

    In another case, there was a failure of identical equipment in both the plants, at nearly the same time. An RCA can clarify on operational aspects, maintenance aspects, and material supply issues or others. In other words, conducting an RCA will help in reducing the cost of maintenance (and thus WII).

11. Differences in type and number of WOs and WII in both the plants in the sample periods were considered. Many factors lead to this variation including, but not limited to, the very characteristics of maintenance activity, differences in the reliability of equipment in both the plants, local layout conditions, plant operating conditions, proximity of these plants to other corrosive environments (the complex has many other plants as well), the skill level of operating personnel.

12. Forecasting the total number of WOs in each plant is carried out using various trend line options available in MS Excel and shown in TABLE II.

Factors that may affect these trends include but are not limited to, reliability issues, breakdowns, short shutdowns, and special initiatives.

Forecasting total WII in each plant using various trend line options available in MS Excel gave very poor results (large error). However, the total maintenance cost (cost associated with WOs that were closed and that associated with open WOs) is not used, as the cost associated with closed WOs in these periods was not available. So, a relation between total maintenance cost and the time couldn't be explored.

TABLE II. PREDICTION

Plant	Data points considered	Options with best results	Actual value / Forecasted value
P1	3	Exponential Linear Power	117/117 117/117 117/117
	4	Logarithmic Polynomial, Order 2 Power	124/116 124/116 124/116
P2	3	Polynomial, Order 2	109/106
	4	Polynomial, Order 2	111/107

13. Analyzing the distribution of WOs helps in understanding the characteristics of maintenance activities in both plants. For similar plants, the characteristics are different. T1 type and T2 type WOs form a major part of total WO. Refer to TABLES III & IV and Fig. 1 & Fig. 2.
14. Distribution of WII shows differences in maintenance activity, and a major share of WII was associated with T1 type WO in both plants. Refer to TABLES V & VI and Fig. 3 & Fig. 4.

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TABLE III. WO DISTRIBUTION – P1 PLANT

Month	Plant	T1%	T2%	T4%	M3%	M8%
1	P1	45.5	26.4	12.4	12.4	3.3
2	P1	41.1	35.5	10.6	10.6	2.1
3	P1	33.6	34.5	13.6	13.6	4.5
4	P1	35.9	35.0	12.8	12.8	3.4
5	P1	39.5	32.3	12.1	12.9	3.2

TABLE IV. WO DISTRIBUTION – P2 PLANT

Month	Plant	T1%	T2%	T4%	M3%	M8%
1	P2	21.0	49.0	10.0	8.0	12.0
2	P2	23.3	47.6	9.7	7.8	11.7
3	P2	23.3	47.6	9.7	7.8	11.7
4	P2	25.7	46.8	9.2	7.3	11.0
5	P2	26.1	45.0	10.8	7.2	10.8

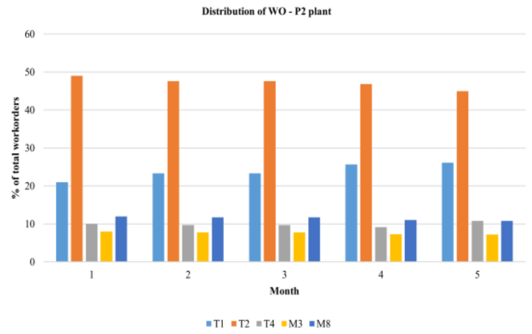

Fig. 1. WO distribution – P1 plant

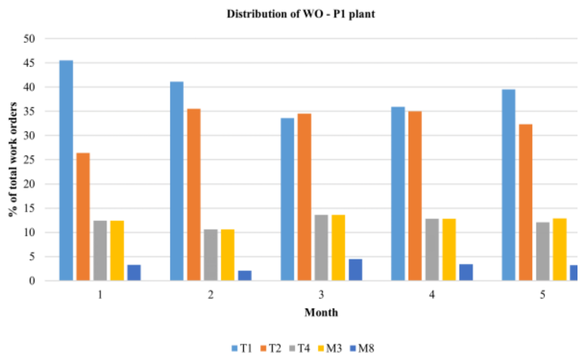

Fig 2. WO distribution – P2 plant

TABLE V. WII DISTRIBUTION – P1 PLANT

Month	Plant	T1%	T2%	T4%	M3%	M8%
1	P1	83.4	12.5	0.0	0.0	4.1
2	P1	92.9	7.1	0.0	0.0	0.0
3	P1	72.4	25.7	0.0	0.0	1.8
4	P1	95.8	4.2	0.0	0.0	0.0
5	P1	87.0	7.4	0.0	5.5	0.0

TABLE VI. WII DISTRIBUTION – P2 PLANT

Month	Plant	T1%	T2%	T4%	M3%	M8%
1	P2	94.7	5.3	0.0	0.0	0.0
2	P2	94.6	5.4	0.0	0.0	0.0
3	P2	89.5	10.5	0.0	0.0	0.0
4	P2	89.6	10.4	0.0	0.0	0.0
5	P2	-52.9	152.9	0.0	0.0	0.0

-ve value is due to the return of excess material to stores; WO types with zero WII not seen on the chart. With –ve WII, total WII < WII for T2 type wos

15. From TABLE VII and raw data, the majority of the WII is associated with T1 type WO under the corrective repairs and scheduled overhauls category. TABLE VII shows data for months 1 to 5.

TABLE VII. T1 WO AND TOTAL WO – P1 & P2 PLANTS

Plant	T1 WO as % of total WO	T1 WII % of total WII	Plant	T1 WO as % of total WO	T1 WII % of total WII
P1	45.5	83.4	P2	21.0	94.7
P1	41.1	92.9	P2	23.3	94.6
P1	33.6	72.4	P2	23.3	89.5
P1	35.9	95.8	P2	25.7	89.6
P1	39.5	87.0	P2	26.1	-52.9

-Ve Value Is Due To The Return Of Excess Withdrawn Material And Exceeding The Wii

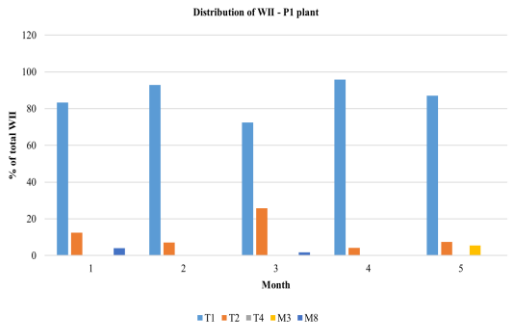

Fig. 3. WII distribution – P1 plant

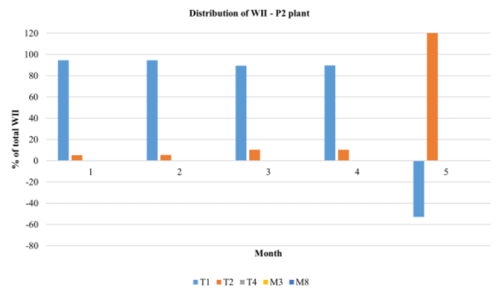

Fig. 4. WII distribution - P2 plant

16. From TABLES VIII & IX, it is seen that a lower percentage of WOs results in a significant WII (This is more pronounced in P2). If it is assumed that the WII indicates the total cost of maintenance under the T1 type of WOs, then the cost of corrective repairs is high.

TABLE VIII. WII FOR T1(C) & T1, NUMBER OF T1(C) & T1 – P1 PLANT

Month	Plant	WII T1(C) / WII T1 %	Number of T1(C) / Number of T1 %
1	P1	91.0	40.0
2	P1	32.0	24.1
3	P1	54.6	32.4
4	P1	19.7	21.4
5	P1	12.5	40.8

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TABLE IX. WII FOR T1(C) & T1, NUMBER OF T1(C) & T1 – P2 PLANT

Month	Plant	WII T1(C) / WII T1 %	Number of T1(C) / Number of T1 %
1	P2	96.5	33.3
2	P2	96.6	29.2
3	P2	95.2	29.2
4	P2	66.7	17.9
5	P2	-36.1	55.2

17. Reasons for the lower total WII for the 5th month (as compared to other months) include the absence of WOs involving equipment overhauling, corrective maintenance (with WII) and a lack of consumables reservation. The consensus is that maintenance activities often exhibit a lack of systematic behavior.
18. Within the considered sample period for data, the life of open WOs (WO start date to WO closure date) is 5 months or more (WOs existed before the start of sample data and existed till the end of the sample data period). A summary of various causes for this problem, found by conducting RCAs is:

- Return of excess material withdrawn (a cumbersome process)
- Management is not serious about this data
- Review parameters not changing through various leaderships (earlier reviews never considered this problem)
- Non-closure not seriously reviewed
- Job accountability is not clearly defined
- Long-duration job activities (like repairing by an outside agency) involved in the total job
- Lower job criticality
- Improper job planning
- Working with partial spares/waiting for spares

19. Delay in closure, of T1(C) type WOs that were breakdowns using spares and T1(C) type WOs that were corrective repairs that used spares, was noticed with 17 WOs. The age of WOs from initiation to closure was considered. The age was found to vary between 0.25 and 28 months with an average of 3.1 months (WOs existed before the start of the sample period and closure date within the sample period considered). A summary of various causes for this problem, found by conducting RCAs is:

- Return of excess material withdrawn (a cumbersome process)
- Management is not serious about this data
- Review parameters not changing through various leaderships (earlier reviews never considered this problem)
- Non-closure not seriously reviewed
- Job accountability is not clearly defined
- Long-duration job activities (like repairing by an outside agency) involved in the total job
- Improper job planning
- Inefficient maintenance audit process

20. Incorporating a preventive strategy to reduce corrective maintenance is a widely accepted approach. With the data available, it remains uncertain whether the equipment that underwent corrective repairs during the sample period received any prior preventive maintenance measures. Thus a correlation between preventive actions and corrective actions could not be established (whether preventive maintenance of equipment will lead to a reduction in corrective maintenance or not). However, a relation between the number of T2 and T1(C) orders was established (only the numbers were considered) by finding a correlation coefficient using the CORREL( ) function in Excel. This correlation only shows whether the number of T2 and T1(C) WOs are positively or negatively correlated. A negative and moderate correlation was found in the P1 plant, while a weak correlation was found in the P2 plant.

V. EXTRA POINTS FOR REVIEW

A. Existing monitoring

- Only WOs and WII numbers are reviewed, without examining deviations
- Review of % of planned jobs, % of reactive jobs
- Review of inventory turns
- Review of safety performance
- Review plant availability number

B. Proposed improvements

The following are proposed in addition to the existing points being reviewed.

- To minimize duplication, only planners or a limited number of personnel should be authorized to generate WOs and held accountable
- Workshop machining facilities should be reviewed and enhanced (if needed) to meet the quality requirements of components being machined
- Establish a system of creating dimensional drawings, material specifications, and tolerances for components to be machined at the workshop
- Review the RCA work process and adhere to it
- A specific timeframe should be set for plant personnel to hand over excess materials to the stores, and for the stores to update the material system accordingly
- Develop a system for WO description keyword standardization
- There were WOs about corrective repairs that required the usage of spares but were not withdrawn against the corresponding WO. Not withdrawing the needed spares from stores may be due to storing spares in a local workshop, or withdrawing the spares using another WO unrelated to this corrective repair. This may result in improper inventory accounting. Conduct audits of the WO process and activity, periodically
- Develop a program to reduce the number of corrective maintenance activities, as the cost of corrective maintenance is high
- Periodically review and update preventive maintenance schedules to reduce the WII (and also the total cost of maintenance)
- Develop and maintain a process of job planning
- Review all deviations

VI. AREAS FOR FURTHER STUDY

- Collect WO data every month and update the trends. Trying different trend lines can also be attempted
- After the above, utilize that data when preparing future budgets and predicting the portion of the budget that needs to be released periodically
- Use the total maintenance cost (WII + cost in closed WOs in that period) and rate of production to determine if prediction (with low error) is possible
- Consider data over a longer period to assess the impact of preventive actions on corrective actions in both plants

REFERENCES

[1] Analysis of the Maintenance Work Order Data in Educational Institutions, May 2019, Proceedings of International Structural Engineering and Construction, Deniz Besiktepe, Mehmet E. Ozbek, Rebecca A Atadero

[2] Franke, Jacob A., "Investigating the Relationship of Preventive and Corrective Maintenance in Chiller Assets Using Linear Regression Analysis" (2022). Theses and Dissertations. 5396

ABBREVIATIONS

WO	Work Order
WII	Work In Inventory
T1(C)	T1 type WO – Corrective repairs
WOs	Work orders
RCA	Root cause analysis