

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

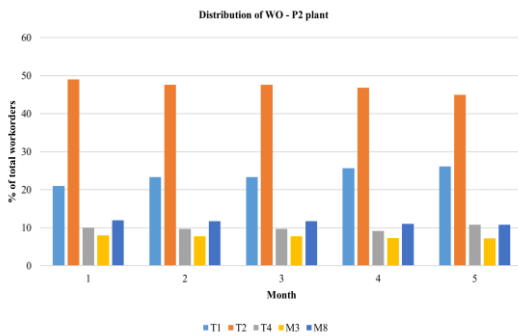


Fig. 1. WO distribution – P1 plant

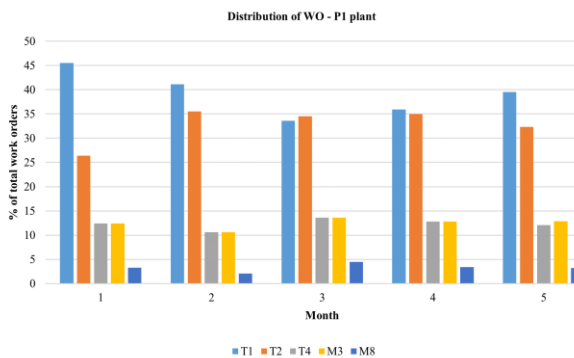


Fig 2. WO distribution – P2 plant

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 was

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-Ve Value Is Due To The Return Of Excess Withdrawn Material And Exceeding The WII

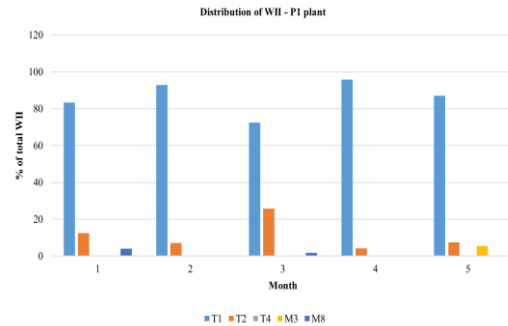


Fig. 3. WII distribution – P1 plant

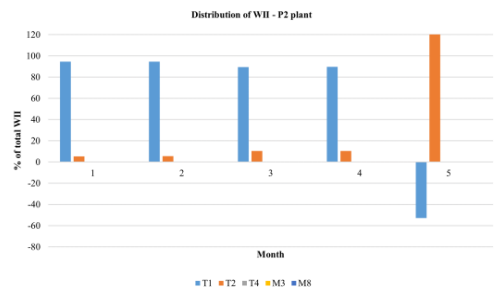


Fig. 4. WII distribution - P2 plant

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

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