Ilkogretim Online - Elementary Education Online, 2021; Vol 20 (Issue 5): pp. 7095-7103
http://ilkogretim-online.org
doi: 10.17051/ilkonline.2021.05.802

Industrial Maintenance: Key Performance Indicator Growth and Obsolescence Management

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Abstract: Maintenance has become increasingly important as time has passed since the mid-nineteenth century's industrialization. Even though many organizations still consider proactive maintenance to be an expense rather than an investment, it has become increasingly important. The importance of KPIs and obsolescence management in maintenance operations are highlighted in this paper. The first step was to develop a new KPI to evaluate maintenance work and compare it to production work. Even though ISO 15341:2007 specifies specific KPIs, a new one was required. As a result, a two-phase KPI was created, with its values matched to a decision matrix that provided a qualitative assessment of the work performed. The second step was to develop a decision-making tool for assessing electronic component obsolescence and selecting a mitigation strategy. The IEC 62402:2007 standard specifies some terminology and conditions for determining obsolescence, but it does not specify whether a proactive or reactive approach should be used. The KPI is also a two-phase process, as it was developed. The first phase aids in determining which components are more likely to become obsolete, while the second phase assesses the consequences of that obsolescence. The results are also connected to a decision matrix, determining whether the mitigation strategy should be proactive or reactive. In a dairy processing factory, the novel KPI and obsolescence approach was successfully tested in practice, demonstrating that it perfectly meets the initial goals.

Keywords: Proactive maintenance, Obsolescence, Key performance indicators, KPI, Maintenance, Maintenance management

I. INTRODUCTION:

Regardless of the industry, maintenance has evolved from a relatively frivolous and straight forward task to becoming increasingly important over time. This has grown from simply repairing broken equipment to a more complex and scientifically driven process [1]. In addition, the maintenance role has become so crucial in today's market that most businesses must strive to have a well-implemented process and manage this task [2]. Indicators can help prioritize which sectors and functions to implement in any production system and assist with maintenance tasks [3–5]. The military was the first industry to be directly impacted by obsolescence issues, and as a result, it was also the first to develop tools to address the problem [6, 7]. This project aimed to create a Key Performance Indicator (KPI) that would allow a company to assess the work done on maintenance activities and a model for determining the obsolescence of electronic components in machines on a production line. To help validate the novel KPI and obsolescence approach model, case studies were developed. Maintenance is defined as all operations required to maintain or restore an equipment's ability to perform its task, according to ISO 13306:2010 [8]. For monitoring, maintenance can be divided into two main philosophies. These can be either proactive or reactive. Proactive maintenance is defined as all maintenance operations performed before a breakdown or stoppage occurs. In contrast, reactive maintenance is defined as the act of performing said operations after a breakdown or stoppage has been detected [9]. The Fig.1 depicts how these two significant philosophies diverge. As the need for improved and more robust maintenance processes has grown, more reliable and readable data has grown to support those processes [10]. KPIs have become increasingly crucial in maintenance management as a result of this more reliable data collection. Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR), and Overall Equipment Effectiveness (OEE) are the most common maintenance indicators [11]. The standard ISO 22400-1:2014 [12] lists the KPIs that can be used for maintenance activities, separating them from technical, economic, and organizational KPIs.

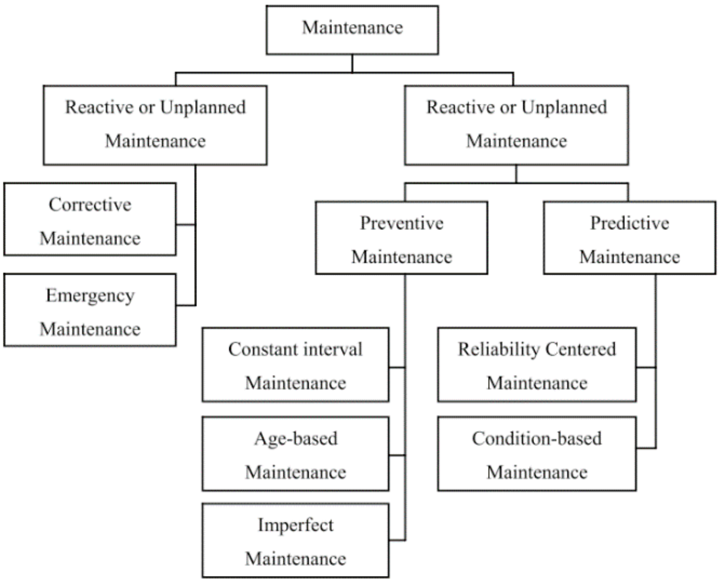

Fig. 1. Different types of maintenance

Obsolescence is another issue that can have a long-term impact on businesses [13]. Obsolescence can be confirmed for a particular component if it does not perform as intended or if the original supplier no longer supplies it [14]. Given the shift from using specially designed electronics, which would take longer to become obsolete, to using primarily “Commercial of the shelf components” [7], this is a recurring problem in the military industry. This paper’s methodology can be broken down into four stages. The first stage resulted in a review of the literature on maintenance, obsolescence management, and industry KPIs. The second stage involved gathering data for the variables needed for both the KPI and the obsolescence model and developing both tools. The third stage involved creating a case study to evaluate the validity and model of the KPI. Finally, the results of both case studies were analyzed, and conclusions were drawn about the validity and utility of the KPI and model in the fourth and final stage.

II. Industrial Maintenance KPI Analysis and Obsolescence Management:

2.1 Establishment of KPIs:

The study was based on previously developed KPIs to establish a link between maintenance work and the volume of work completed by an industrial unit. Given the lack of a KPI to link maintenance activities to a company's volume of work, it was necessary to examine the various data sources available at a plant and determine how they could be linked, allowing for a good correlation between these variables. The KPI that will be developed should be simple to calculate using data collected by the maintenance and production functions. The designed KPI can be described as a two-phase process. The first phase focuses on maintenance work and compares reactive and proactive operations in a single equation. The second phase is carried out in the same way as the first, except that the work completed in both reactive and proactive processes is compared to the work completed in production. These two phases are known as RPR and MPR, or Reactive-Proactive Ratio and Maintenance-Production Ratio, respectively. Equations (1) and (2) show how to perform the required calculation.

$$RPR = \frac{T_{reactive}}{T_{proactive}} \times \frac{N_{reactive}}{N_{proactive}} \times \frac{C_{reactive}}{C_{proactive}} \qquad (1)$$

$$MPR = \frac{T_{reactive+proactive}}{T_{production}} \times \frac{N_{reactive+proactive}}{N_{set-ups}} \times \frac{C_{reactive+proactive}}{C_{production}} \qquad (2)$$

The following are their variables:

- $T_{reactive}$: Total time during reactive maintenance operations, during a certain time period;
- $T_{proactive}$: During a specific period, the total time spent on proactive maintenance operations;
- $T_{production}$: During a specific period, the total time spent in actual operation;

- $N_{reactive}$: The number of maintenance operations that are performed as a result of a reactive situation, during a certain time period;
- $N_{proactive}$: The number of preventative maintenance procedures, during a certain time period;
- $N_{set\text{-}up}$: Number of set-ups, during a certain time period;
- $C_{reactive}$: Reactive maintenance operations are expensive, during a certain time period;
- $C_{proactive}$: The cost of preventative maintenance, during a certain time period;
- $C_{production}$: Production costs, during a certain time period.

Both values must then be assessed in terms of the value they provide. The intervals in which these should be evaluated are shown in Tables 1 and 2. Following the calculation of RRP and MPR, the values must be matched to a decision matrix. Figure 2 depicts the decision matrix.

RPR	**Evaluation**
0≤RPR≤0,15	Excellent state of the equipment
0,15<RPR≤0,25	Depending on variable values, it can be determined whether the process or the equipment has some issues.
0,25<RPR≤0,5	Still in good working order. An assessment should be carried out to determine whether the problem stems from the equipment or the process itself.
RPR>0,5	It is necessary to determine what needs to be done to correct any malfunctions that have occurred.

Table 1. RPR evaluation parameters

MPR	**Evaluation**
0<MPR≤0,01	The production is running smoothly, and the equipment is working as anticipated.
0,01<MPR≤0,03	Production is going well, and the equipment is performing admirably.
0,03<MPR≤0,05	Production with acceptable results, on the other hand, might be required to evaluate process improvements.
MPR>0,05	Possible causes of poor performance should be evaluated, and immediate steps should be taken to minimize the same causes.

Table 2. MPR evaluation parameters

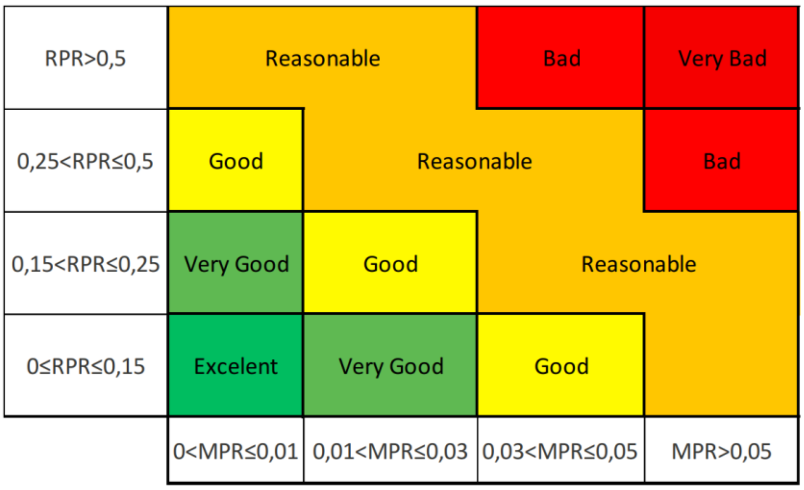

Fig. 2: KPI decision matrix

2.2 Obsolescence model development:

The model's goal is to determine the state of obsolescence of electronic components in the production line's equipment. The equipment in question in the case study that follows is cheese slicing machines, which are easily replaceable despite having a lot of mechanical components. Electronic parts, by their very nature and in today's market, may be difficult to replace. This model, like the KPI, is divided into two phases. The first phase assesses obsolescence and determines which component is more critical to the equipment's ability to perform its function. The second phase considers the effects of actions taken to prevent obsolescence on the production system. Each variable in this model will be assigned a value ranging from 1 to 4, from worst to best. This value will be multiplied by a decision weight, which is expressed as a percentage, and then added to the importance of other variables to produce a result for that phase. The variables and criteria used to determine the values to be used shown in Tables 3 and 4. Some concepts to retain for this model are: i) Book value (BV) - The financial value of the asset, after netting it against its depreciation; ii) Replacement asset value (RAV) - The cost required to restore a certain asset to its original state. It is necessary to compare the values with a decision matrix after calculating the values for both phases. This decision matrix is depicted in Figure 3. Following this procedure, the most appropriate approach to dealing with obsolescence issues in a few selected components should be obtained.

Variable	**1**	**2**	**3**	**4**	**Decision weight**
Replacement capacity	There are no alternatives to the component analyzed	No alternatives to the component on the market but still available in stock	Component can only acquire in third parties and/or still available on stock	Component can still be acquired through its main supplier and/or still available on stock.	40%
Age assessment	x>5 years	5≥x>3 years	3≥x>2 years	2≥x≥0 years	10%
Machine relevance	Equipment does not function without component	Equipment function in manual mode without the component.	Equipment works on automated mode without component with limitations.	Equipment works without limitations, without the component.	40%
BV/RAV Ratio	x<25%	25%≤x<50%	50%≤x<75%	75%≤x	10%

Table 3. First phase model variables

Variable	**1**	**2**	**3**	**4**	**Decision weight**
Equipment replacement forecast	x>5 years	5≥x>3 years	3≥x>2 years	2≥x≥0 years	15%
Component price	≥5% of RAV	3%≤x<5% of RAV	1%≤x<3% of RAV	<1% of RAV	25%
Retrofit difficulty	Component replacement as well as major changes in the equipment.	Component replacement and considerate changes in the equipment	Component replacement and minor changes in the equipment.	Mere replacement of component	30%
Retrofit cost	≥10% of RAV	5%≤x<10% of RAV	2%≤x<5% of RAV	<2% of RAV	30%

Table 4. Second phase model variables

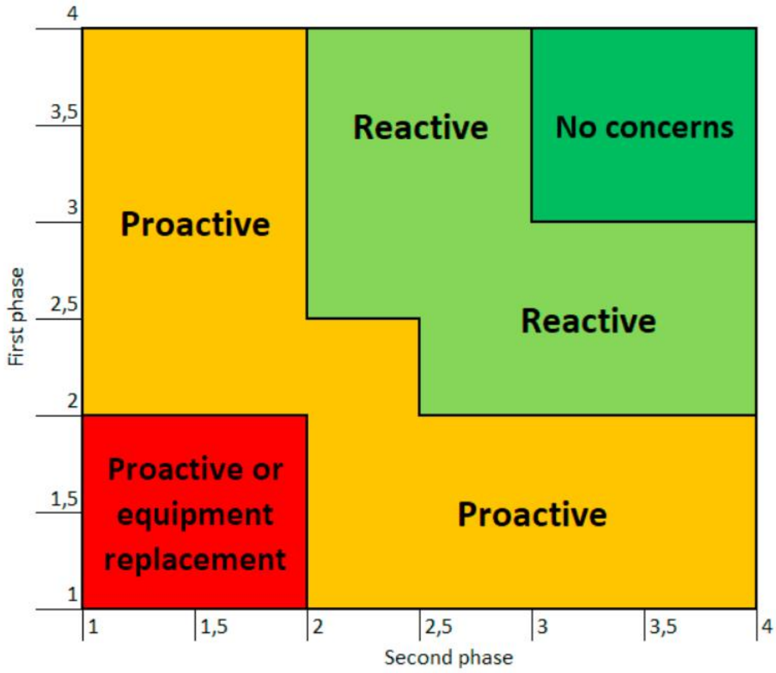

Figure 3. Obsolescence model decision matrix

III. Results and Discussion

3.1 KPI implementation:

Different time slots were used for the KPI test. The first test involved analyzing RPR and MPR on a monthly basis. Each subsequent test increased the time slot to a quarter, half a year, and finally a full year. This is to see what kinds of results can be obtained when different time scales are used. The data for these tests were obtained from an analysis of one of the production lines in the cheese slicing sector, which was the factory's most critical sector and where this study was conducted. The monthly, quarter, half-year, and year studies are shown in Tables 7 and 8, respectively. In these tests, it can be seen that the longer the study period, the less significant the result, which is subject to outliers. Another feature of this KPI is that it can provide a more comprehensive view of both maintenance and production results in the same step. Months 6, 10, 11, and 12 are given a "Reasonable" rating despite their RPR being greater than 0.5. Month 7 has a shorter evaluation than month 9, even though the RPR for the latter is significantly higher due to the different production parameters for each month. The results of the other studies have been more evenly distributed.

Month	Number of reactive	Time of reactive (t.u.)	Cost of reactive (m.u.)	Number of proactive	Time of proactive (t.u.)	Cost of proactive (m.u.)
1	14	265	6 503	19	1 068	22 191
2	21	406	9 007	18	1 644	30 862
3	19	309	6 061	28	5 262	95 803
4	43	900	20 349	21	2 280	57 450
5	24	515	10 938	17	690	17 614
6	79	1 854	38 622	21	1 464	27 801
7	101	2 036	39 166	22	4 770	87 447
8	45	1 363	26 859	18	4 248	77 448
9	69	2 463	47 613	23	858	15 884
10	34	988	23 808	19	1 434	27 898
11	29	849	16 024	18	582	10 600
12	69	1 635	33 361	20	900	17 839

Table 5. Maintenance data for RPR and MPR calculation

Month	Number of set-ups	Production time (t.u.)	Production cost (m.u.)
1	25	27 510	915 644
2	26	26 458	860 868
3	33	34 228	1 157 107
4	21	25 993	776 756
5	31	32 160	929 301
6	31	33 698	930 666
7	28	36 004	1 114 306
8	28	36 103	1 222 894
9	22	25 135	794 052
10	24	27 565	929 690
11	32	30 285	1 009 933
12	29	31 535	1 067 314

Table 6. Production data for MPR calculation

Month	RPR	MPR	Evaluation
1	0,05	0,002	Excellent
2	0,08	0,005	Excellent
3	0,00	0,020	Very good
4	0,29	0,037	Reasonable
5	0,65	0,002	Reasonable
6	6,62	0,023	Reasonable
7	0,88	0,094	Very bad
8	0,28	0,030	Reasonable
9	25,81	0,044	Bad
10	1,05	0,011	Reasonable
11	3,55	0,002	Reasonable
12	11,72	0,012	Reasonable

Table 7. RPR and MPR results for the monthly study

Analysis	Time	RPR	MPR	Evaluation
Quarter	First	0,099	0,008	Excellent
	Second	2,220	0,014	Reasonable
	Third	2,632	0,054	Very bad
	Fourth	7,234	0,007	Reasonable
Semester	First	0,201	0,011	Good
	Second	1,663	0,023	Reasonable
Annual		0,688	0,017	Reasonable

Table 8. RPR and MPR results for the quarter, semester and year study

3.2 Obsolescence model:

Three of the slicing lines' components were chosen for this stage. The factory had identified these components as potential obsolescence hazards. The data collected from these production lines are shown in Table 9.

Production line	Year of acquisition	RAV (m.u.)	BV (m.u.)	Obsolescent components
1	2002	243 500		2
2	2003	274 000		2
3	2005	306 000	50 997	1

Table 9. Slicing machines characteristics

In the factory, there are four production lines. One of the lines, on the other hand, shows no signs of becoming obsolete. Two of the remaining three books have a negative book value. This is because both of these lines have already been fully amortized. Due to confidentiality concerns, the components will be identified by a two-digit number, the first of which codes the line and the second of which represents the element, separated by a dash. Tables 10, 11, and 12 show the results from the first phase in each production line.

Variable	1-1	1-2
Replacement capacity	3	3
Age assessment	1	1
Machine relevance	1	1
BV/RAV Ratio	1	1
Total	1,8	1,8

Table 10. First phase results for Line 1

Variable	2-1	2-2
Replacement capacity	3	3
Age assessment	1	1
Machine relevance	1	1
BV/RAV Ratio	1	1
Total	1,8	1,8

Table 11. First phase results for line 2

Variable	3-1
Replacement capacity	1
Age assessment	1
Machine relevance	1
BV/RAV Ratio	1
Total	1

Table 12. First phase results for line 3

Given the similar period in which these machines were purchased, the functional similarity of the components, and an equal RAV value, their results for the first phase for lines 1 and 2 are identical. Line 3 receives a total of line 1 because the component in question is unavailable from its original supplier, third parties, or is in stock despite being older than the other two lines. The second phase of the production lines is shown in Tables 13, 14, and 15.

Variable	1-1	1-2
Equipment replacement forecast	3	3
Component price	2	2
Retrofit difficulty	1	1
Retrofit cost	2	2
Total	1,85	1,85

Table 13. Second phase results for line 1

Variable	2-1	2-2
Equipment replacement forecast	3	3
Component price	3	2
Retrofit difficulty	1	1
Retrofit cost	2	2
Total	2,1	1,85

Table 14. Second phase results for line 2

Variable	3-1
Equipment replacement forecast	3
Component price	2
Retrofit difficulty	1
Retrofit cost	3
Total	2,15

Table 15. Second phase results for line 3

All lines are scheduled to be replaced in the next three years. Because of this, the value for "Equipment replacement forecast" is shared by all components. Given the state's assessment on line 3 for the first phase, it was necessary to work out a budget with the supplier for a quick retrofit. When compared to the decision matrix, the results are shown in Table 16.

Component	First phase	Second Phase	Type of approach
1-1	1,8	1,85	Proactive or equipment replacement
1-2	1,8	1,85	Proactive or equipment replacement
2-1	1,8	2,1	Proactive
2-2	1,8	1,85	Proactive or equipment replacement
4-1	1	1,8	Proactive or equipment replacement

Table 16. Results for the obsolescence model

At the very least, all of the components evaluated must take a proactive approach to obsolescence management. However, for all of the lines assessed, it may be necessary to replace the equipment entirely. However, because this last option is too expensive in the short term, it would be preferable to try to retrofit all of the machines instead and then find replacement alternatives to those same machines later.

IV. Conclusions

The main goal of this paper was to create two tools to help a maintenance department manage its day-to-day operations. This can be said to have been accomplished. Despite the fact that these two tools were developed in a dairy processing plant, they can be applied to any industry depending on their unique requirements. It is recommended that the KPI be used in quarters. Because maintenance improvements can take some time to assess their random nature, this method is less susceptible to outliers that can distort the results. This does not rule out the possibility of using it for shorter or even more extended periods. Furthermore, depending on the industry in which this KPI is used, its benchmarks can be changed. The obsolescence model is in the same boat. It doesn't mean it can't be used with mechanical components because it's applied to a set of electronic components. The sample used to analyze, on the other hand, was quite similar throughout, which is the main reason why most values were quite similar to one another. In addition, identical to KPIs, this tool can be customized to meet the goals of a different organization. For example, an organization could assign a higher or lower "Decision weight" to any of the variables and switch the evaluations from the decision matrix to a more appropriate one.

ACKNOWLEDGMENT

We acknowledge the support of time and facilities from Ho Chi Minh University of Technology (HCMUT), VNU-HCM for this study.

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