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THE IMPACT OF MAINTENANCE ON PROFITABILITY A CASE STUDY IN FOOD PACKAGING

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Abstract

The purpose of this paper is to study and present the impact of maintenance as one of the competitive factors in the business strategy. A financial maintenance model is developed to illustrate that maintenance can have a significant impact on a firm's profitability. The model incorporates return on capital as a means to measure the effectiveness of maintenance activities. The results from simulation analysis indicate that variations in maintenance policies can impact return on capital and profitability of a business.

Key words : maintenance, return on capital, simulation.

INTRODUCTION

The maintenance function is often overlooked by management as a competitive factor in the firm's business strategy. Most managers regard equipment maintenance as a necessary evil or a service whose sole purpose is to react in emergency situations. The maintenance function should be viewed by management as a resource that can be used strategically to improve productivity and profitability. Achieving effective maintenance could be of benefit to companies, which can increase profit by the reduction of maintenance costs, as well as to customers who can enjoy improvement of service quality. Management can improve profitability by focusing more attention on maintenance costs themselves. Since plant engineering and maintenance comprise approximately 10 to 40 percent of controllable manufacturing costs, management has the opportunity to increase profits by reducing these costs. Nevertheless, top management typically spends only 2 to 3 percent of its time on controlling maintenance costs that arise because of problems (Rishel T. D., 2006). Instead of managing maintenance activities proactively, management controls maintenance expenses reactively. The purpose of this case study is to justify incorporating maintenance as a competitive factor in the business strategy. Support for this premise is based on profitability. A maintenance contribution model is developed which incorporates return on capital (ROC) as a means to measure the effectiveness of maintenance activities. A range of maintenance policies reflecting varying levels of activity are evaluated in terms of their impact on revenue, costs, profit, and ROC.

MATERIAL AND METHODS

The maintenance activities within this study are categorized as either planned maintenance or emergency maintenance. Planned maintenance includes both preventive and predictive maintenance activities while emergency maintenance is performed only after equipment has failed. A universally recognized outcome of planned maintenance is a reduction in failures. Typically, an increase in planned maintenance decreases emergency maintenance.

The maintenance model is based on the fact that various maintenance policies incorporating a range of planned maintenance activities impact the number of times a piece of equipment fails. The change in the number of failures changes the mean time between failures (MTBF) and downtime for repair, thereby impacting equipment availability. The change in availability allows the company to vary its output level, which in turn affects sales revenue and production costs. Maintenance costs are also affected as the level of emergency and planned maintenance activities vary. The changes in revenue and costs impact profit and ROC. Figure 1 illustrates these relationships.

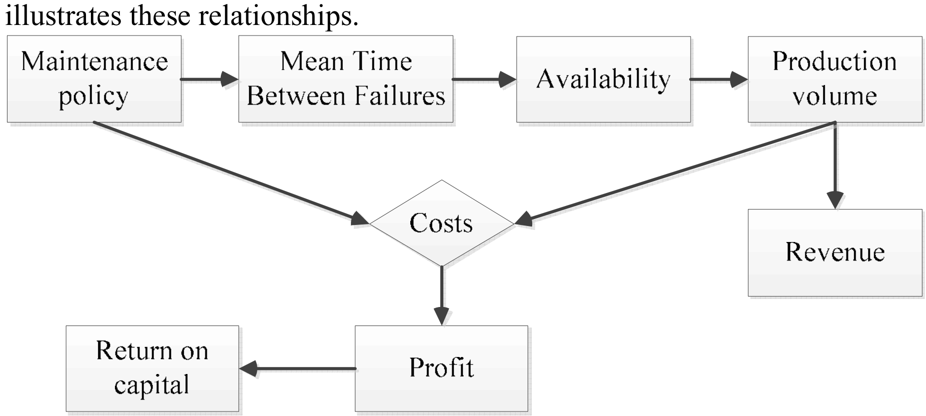

Fig. 1. Resulted maintenance cost model

Two simulation models are used in this study to evaluate a variety of maintenance policies. The simulation model is based on data collected from a firm in the sugar fabrication industry. The simulation models three independent packaging machines subject to failures. Jobs are generated for each machine over the course of a year according to data supplied by the company. As the machines process jobs, failures requiring downtime for repair occur. Varying levels of planned maintenance are added to the simulation in an effort to reduce failures. Data is collected within the simulation for production levels and downtime for emergency and planned maintenance. This information is then used to determine equipment availability and ROC.

Failure data are collected and used to identify the failure characteristics of each machine. By using the Kolmogorov-Smirnov test it is found that each data set is best represented by the Weibull distribution; a distribution often used to model equipment failures. The Weibull distribution is defined by a scale and shape parameter. The scale parameter represents MTBF and the shape parameter represents failure rate. A shape parameter of 1.0 represents a constant failure rate. However, as the shape parameter increases the probability of a failure occurring increases as well. The Weibull distribution for Machine 1 is characterized by a MTBF of 6,400 minutes (used as the scale parameter) and a shape parameter of 1.34. Machine 2 is characterized by a MTBF of 4,584 minutes and a shape parameter of 3.37, and Machine 3 is characterized by a MTBF of 10,187 minutes and a shape parameter of 2.43. Downtime for repair after a failure averages 360 minutes for Machine 1, 686.4 minutes for Machine 2, and 105 minutes for Machine 3. A triangular distribution is used in the simulation model to represent repair time.

Five maintenance policies for each machine are simulated over the course of a year to determine the policies' effect on reducing failures. The policies represent alternatives the company was considering at the time the data were collected.

Policy 1. Emergency maintenance only. This policy serves as the basis for comparison as scheduled maintenance is added.

Policy 2. Planned maintenance for each machine every two weeks.

Policy 3. Planned maintenance for each machine every week.

Policy 4. Planned maintenance for each machine twice weekly.

Policy 5. Planned maintenance for each machine every day.

Machines 1 and 2 are down 60 minutes each when a maintenance action is planned. Machine 3 is down 40 minutes for each planned maintenance action. The simulation model is replicated twenty times for 525,600 minutes (one year) per replication for each maintenance policy. The output data collected during the simulation are used to determine revenue and production costs for each maintenance policy. In addition, the downtime for emergency maintenance and planned maintenance is factored by hourly maintenance costs supplied by the company to determine the total maintenance cost. For this company the hourly emergency maintenance cost is 1.06 times greater than the hourly planned maintenance cost. These values are used in model to calculate ROC for each policy. The simulation also provides machine availability for Machines 1, 2, and 3 for each maintenance policy. This data is used to determine whether planned maintenance makes a difference in available capacity. The ROC and availability results are discussed in the next section. Although these results are not statistically analyzed, they indicate that the impact of maintenance on a firm's financial standing warrants further study. The second simulation, described below, modifies and expands the first simulation to allow for statistical analysis of the results.

The second simulation model again focuses on the three machines and failure characteristics previously described. However, the arrival rate of jobs for processing on the machines is increased to observe the impact of various maintenance policies on availability and ROC under conditions of higher equipment utilization. In addition, ten units of work-in-process inventory are added to each machine queue at the start of the simulation to emulate a steady state manufacturing environment. Four maintenance policies are explored in this study.

Policy 1. Emergency maintenance only. This policy serves as the basis for comparison as planned maintenance is added.

Policy 2. Planned maintenance 6.25 times per year or every 20,000 minutes.

Policy 3. Planned maintenance 12.5 times per year or every 10,000 minutes.

Policy 4. Planned maintenance 25 times per year or every 5,000 minutes.

Policies 2, 3 and 4 are chosen because the time between planned maintenance actions more closely coincide with the MTBF's of Machines 1, 2 and 3. Each maintenance policy is replicated twenty times for 124, 800 minutes per replication. This equates to one 8-hour shift, 5 days per week for 52 weeks.

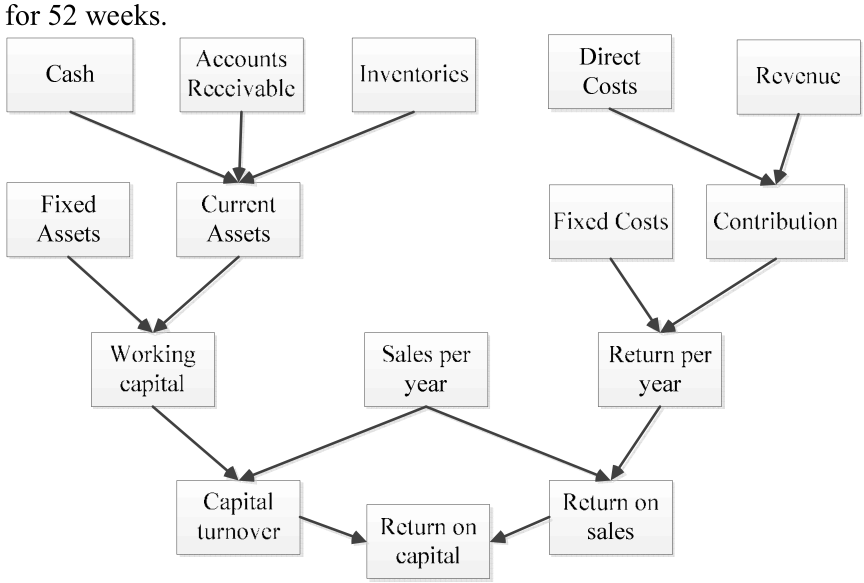

Fig. 2. The model

Data are collected from the simulation to independently calculate and statistically compare availability of each machine as well as ROC. The analysis of variance technique is used to determine if the maintenance policies significantly affect these performance measures. Financial ratios are limited since they can be distorted by a company's operating and accounting procedures. The model is graphically represented in Figure 2 (Rishel T. D., 2006).

Nevertheless, management might expect to see a shift between inventories and cash. If the maintenance policy reduces the number of expected failures, less work-in-process and finished goods inventories are required to cover these unanticipated breakdowns. In addition, by planning and controlling more of its maintenance activities, management can reduce its investment in maintenance, repair, and operating inventories. These savings can be reflected in extra cash or invested in projects with a higher rate of return than inventories. The potential for additional cash may be important for a company since profit does not determine a company's solvency. Maintenance is one more factor a firm can incorporate into its cash planning practices as well as its overall business strategy.

RESULTS AND DISCUSSION

The results from the first simulation establish the fact that the maintenance policy can cause variations in availability and ROC. Table 1 contains these results for each machine and maintenance policy.

Table 1

Return on capital and availability - results for simulation 1

Level of planned maintenance	Return on Capital (percent)	Availability (percent)
Machine 1		
No planned maintenance	11.71	96.99
Two weeks	12.38	97.09
Weekly	12.45*	97.09*
Twice weekly	11.68	96.92
Daily	0.98	95.04
Machine 2		
No planned maintenance	10.90	96.86
Two weeks	12.25	97.07
Weekly	14.17	97.38
Twice weekly	20.72*	98.40*
Daily	9.23	96.39
Machine 3		
No planned maintenance	23.97*	99.90
Two weeks	18.92	99.81
Weekly	13.82	99.72
Twice weekly	-15.50	99.20
Daily	-104.47	97.66

* Highest return on capital and availability

As shown in the table, Machines 1 and 2 experience their highest ROC and equipment availability when planned maintenance is incorporated into the maintenance policy. However, the appropriate level of planned maintenance is different for each machine. Machine 1 responds better when planned maintenance is performed weekly, whereas Machine 2 responds better when planned maintenance occurs twice weekly. Machine 3 experiences the highest levels of availability and ROC when the emergency maintenance policy is in effect.

The emergency maintenance policy for Machine 3 is most effective because the machine is utilized at a much lower rate than Machines 1 and 2. Since a failure does not occur unless the machine is operating, and since Machine 3 has a MTBF of 10,187 minutes (based on operating time), there are few failures during the course of a year. There is not any advantage for the company to perform planned maintenance on this machine because the time and expense for this activity outweighs that of the emergency maintenance policy. Based on the production orders provided by the company for these machines, the simulation results show that only Machine 1 is incapable of processing all of its orders during the year. Alternatively, Machines 2 and 3 are not fully utilized throughout the year. Therefore, these two machines can process all orders to completion. These results imply that the differences seen in ROC among the five policies are solely due to variations in maintenance costs. Revenue and production costs do not change since the production levels for Machines 2 and 3 do not vary, and those for Machine 1 do not vary significantly.

Table 2

Statistical analysis and results for return on capital and availability

Number of planned maintenance actions (frequency)	Return on Capital (percent)	Availability (percent)
Machine 1		
0.00	A 27.25	A 91.35
6.26	A 28.65	A 91.35
12.50	A 28.90*	A 92.55*
25.00	A 27.20	A 91.30
Machine 2		
0.00	A 20.80	A 87.08
6.25	BA 23.65**	BA 88.91**
12.50	B 25.00	B 89.74
25.00	B 25.25	B 89.99*
Machine 2		
0.00	A 31.05	A 93.95
6.25	B 33.05	B 95.29
12.50	C 34.60	C 96.34
25.00	C 35.70*	C 97.03*

* Highest return on capital and availability

** Means with different letters are significantly different from each other for $p < 0.05$

These implications are explored in more detail and a statistical analysis is performed on the results in the second simulation. Because the production orders for the first simulation do not provide an opportunity to evaluate the impact of maintenance on revenue and production costs, a steady stream of jobs is generated for production by each machine. The simulation of Machines 1, 2, and 3 at high levels of utilization expands the study by providing more insight into the relationships between maintenance, availability, and ROC. Table 2 contains availability and ROC results and their statistical significance for the second simulation.

The most important outcome in this simulation is for Machine 3. The increased utilization of Machine 3 requires the adoption of a planned maintenance policy to achieve the highest levels of availability and ROC. This implies that a change in utilization of equipment requires a reevaluation of the appropriate maintenance policy; otherwise the company may not be attaining the highest availability and ROC possible. Production levels, and therefore revenue and production costs, vary for all three machines. Only the variations in revenue among maintenance policies is statistically tested for significance. Machine 3 is the only machine that exhibits any significant differences between revenue. Although Machines 1 and 2 produce production levels that are not statistically different, the variations among revenue and the results for Machine 3 imply that the potential exists to increase production when the appropriate maintenance policy is in effect. The results for the availability measure substantiate this premise. All three machines are available for production a higher percentage of time when planned maintenance is in effect. The highest availability level is significantly higher than the availability level when there is no planned maintenance for both Machines 2 and 3. Likewise, the ROC figures show the same results. In this simulation the ROC is a result of changes in both revenue and direct costs. Although the level of the ROC is not necessarily indicative of what a company can achieve by properly managing maintenance, the fact remains that maintenance does have a significant impact on ROC in some cases. These results illustrate that a company may be hurting itself competitively if the maintenance function is not incorporated as part of its business strategy.

CONCLUSIONS

Although this study may not utilize the cost structure nor the failure characteristics of every company, it does demonstrate that every company should be cognizant of the impact equipment maintenance can have on its financial standing. Top management must start factoring maintenance into their strategies to enhance their competitive positions. The results indicate that by properly utilizing the maintenance function a company can potentially increase its production and revenue through higher levels of availability. This is important for those companies that are capacity constrained. Alternatively, by adopting a maintenance policy appropriate to its equipment, a company can reduce maintenance costs and production costs by reducing disruptions to the production process. Regardless of which financial ratios a company uses, the bottom line is an improvement in profitability.

REFERENCES

1. Cucu, I., Cucu, C., 2009, *Modern management methods for equipment maintenance*, Annales Universitatis Apulensis Series Oeconomica, 11, pp. 827-832

2. Donca, Gh., Mihăilă, I., Ganea, M., Hirțe, D., Nica, M., 2007, *Maintenance role in life cycle management*, în Analele Universității din Oradea, Fascicola Management şi Inginerie Tehnologică, volumul VI, Editura Universității din Oradea, ISSN 1583 – 0691, CNCSIS „Clasa B+", pp. 2158-2163

3. Donca, Gh., 2005, *Optimizarea mentenanţei în fermele zootehnice prin investiţii şi modernizare*, în Analele Universității din Oradea, Fascicula Ecotoxicologie, Zootehnie şi Tehnologii de Industrie Alimentară, volumul IV, Editura Universității din Oradea, ISSN 1583 – 4301, pp. 195-202

4. Donca, Gh., 2010, *Modeling and simulation fault detection and diagnostics of HVAC systems,* în Analele Universității din Oradea, Fascicula Ecotoxicologie, Zootehnie şi Tehnologii de Industrie Alimentară, volumul IX, Editura Universității din Oradea, ISSN 1583 – 4301

5. Donca, Gh., Mihăilă, I. M., 2009, *Aspects of maintenance strategy selection process*, în Analele Universității din Oradea, Fascicola Management şi Inginerie Tehnologică, volumul VIII, Editura Universității din Oradea, ISSN 1583 – 0691, CNCSIS „Clasa B+", pp. 1654-1659

6. Donca, Gh., 2011, *Mentenanța utilajelor şi instalațiilor agroalimentare*, Editura Universității din Oradea, ISBN 978-606-10-0444-7

7. Nica, M., Ganea, M., Donca, Gh., 2008, *Simulation of queues in manufacturing systems*, în Analele Universității din Oradea, Fascicola Management şi Inginerie Tehnologică, volumul VII, Editura Universității din Oradea, ISSN 1583 – 0691, CNCSIS „Clasa B+", pp. 1656-1660

8. Rishel T. D., 2006, *Using a maintenance contribution model to predict the impact of maintenance on profitability,* Journal of Information & Optimization Sciences Vol. 27, No. 1, pp. 21-34

9. Souris, J. P., 1990, *La maintenance, source des profits*, Les Editions d`Organisation, Paris

10. Verzea, I., Gabriel, M., Richet, D., 1999, *Managementul activității de mentenanță*, Editura Polirom, Iaşi

11. http://www.weibull.com