LMSCM2018

16th International Logistics and Supply Chain Congress

Future Trends in Logistics and Supply Chain Management

PROCEEDINGS BOOK

PAMUKKALE UNIVERSITY 1992 DENİZLİ

LODER LOGISTICS ASSOCIATION

NC STATE UNIVERSITY

18-20 October 2018, Denizli/TURKEY

Pamukkale Üniversitesi Kongre ve Kültür Merkezi

www.pau.edu.tr/lmscm2018

LMSCM 2018

16th International Logistics and Supply Chain Congress

October 18-20, 2018

Denizli / Turkey

ISBN: 978-605-81099-1-9

Organized by

Partners

Sponsors

Proceedings of the 16th International Logistics and Supply Chain Congress

October 18-20, Denizli / Turkey

Editors

Prof. Dr. Aşkıner Güngör

Prof. Dr. Mehmet Tanyaş

Assoc. Prof. Dr. Olcay Polat

Prepared for publication by

Zeynep Özsüt Boğar

Zehra Durak

Ahmet Alp Şenocak

Yusuf Yılmaz

Published, December 2018

www.pau.edu.tr/LMSCM2018

CONTENT

MACHINE REPLACEMENT SCENARIO ANALYSIS: A CASE STUDY OF FOOD INDUSTRY

Pornthipa Ongkunaruk[1], Gerrit K. Janssens [2]

Abstract *– The Machine replacement is one of the major problems for a maintenance department. One of the trends in food consumption is the use of ready-to-eat meals. In Asian countries, most meals are an integration of a major part of rice with minor parts of vegetables and/or meat. For ready-to-eat manufacturers, a rice cooker is an important machine to process rice as a main ingredient. Our objectives were to estimate the lifetime of parts of an automatic rice cooker and to determine when to replace the parts by scenario analysis. We studied the worst cast, best case, average case and simulation in two situations: before and after implementing Total Productive Maintenance (TPM). The input parameters included the lifetime and cost of 30 parts of the rice cooker. The lifetimes of the parts were considered as random variables according to probability distributions determined by a simulation software. The output of the simulation was the total maintenance cost of the parts replacement between one and ten years. Next, the lifetimes of parts were determined based on a scenario such as the minimum, maximum and expected values of lifetimes according to the historical data and supplier data. The result showed that the average case model after TPM implementation is the best estimator with 10.55% difference to the actual maintenance cost. The simulation after TPM implementation was the second best method with 16.97% difference. It implied that the TPM implementation was able to lengthen the part life and results in maintenance cost reduction. In addition, the inventories of parts were categorized by ABC classification. It helped the manufacturer to allocate the resources and monitor the right parts. In summary, the average case analysis was the best estimator to determine when to replace a part how much of the maintenance cost of the rice cooker. In the future, this model could support the manufacturer to decide whether it should invest for different types of machines.*

Keywords – Machine Replacement, Simulation, Scenario Analysis, Total Productive Maintenance, Inventory Classification, Spare Parts Inventory Management

INTRODUCTION

Due to changes in structure and work habits of the traditional family unit, the industry offers a wide range of prepared food (e.g. ready-to-cook and ready-to-eat items) (Park and Capps, 1997). Also in Thailand a transition has taken place in food consumption patterns, especially in big cities, with inhabitants with higher incomes, and the younger generation. Food is selected based on less time and skill to prepare. Home-made meals are replaced by ready-to-cook and ready-to-eat foods bought at food stalls, supermarkets or department stores (Kosulwat, 2002).

This study concentrated on a manufacturer of ready-to-eat meals of which the major raw material is rice. The rice cooker is the main machine to cook rice for all ready-to-eat products in the assortment and therefore is very important. A rice cooker is a consumer durable. It has been estimated that the average lifetime of a rice cooker in Japanese households in 8.5 years (Oguchi et al, 2008). In the past, the maintenance department implemented a basic maintenance plan, some parts were replaced often, leading to a high cost and low productivity. A few years ago, the company started to implement the philosophy of total productive maintenance (TPM) for their machines and equipment (Nakajima, 1988). The storage of parts and equipment needs a policy to keep the parts efficiently. Thus, the objectives of this study were to estimate the distribution of the lifetimes of the rice cooker parts and to decide on the replacement time considering scenario analysis. In addition, an appropriate inventory policy of rice cooker parts based on historical data and TPM implementation was determined.

[1] Pornthipa Ongkunaruk, Kasetsart University, Faculty of Agro-Industry, Department of Agro-Industrial Technology, Bangkok, Thailand, pornthipa.o@ku.ac.th
[2] Gerrit K. Janssens, Hasselt University, Faculty of Business Economics, Research Group Logistics, Diepenbeek, Belgium, gerrit.janssens@uhasselt.be

Any production system is vulnerable so it fails from time to time. A failed machine needs to be repaired which causes unproductive time. In production systems, the productive time can be increased by introducing stand-by machines or intermediate buffers. For example, consider a flow-line production system, which consists of a linear sequence of several machines. Since the machines cannot perform their operations when they do not receive input or cannot produce output, the entire production system fails if one machine does. A first solution to this problem is to install secondary (standby) machines in parallel with the primary machines that come into operation when a machine fails. Another solutions is to install buffer storage between successive stages of the production line, unlinking these stages and allowing production to continue while the machines are being repaired (Buzacott & Hanifin, 1978; Sörensen & Janssens, 2004). Many aging machines, like a rice cooker, suffer from deterioration. Due to higher operating and maintenance costs, it might be more economical to replace the machine after a certain time of usage (Verheyen, 1979). A review on equipment analysis appears in Hartmann and Tan (2014). Whether a production system consists of a single machine or a network of machines, maintenance of the system is required, i.e. a combination of technical and administrative actions to retain or restore the system into a state in which it can perform as required. The main reason is that poorly maintained machines or equipment leads to random failures causing unavailability for production, which is directly linked to the profitability of a company. Maintenance requires a maintenance strategy, i.e. a systematic approach to upkeep the equipment involving identification, research and execution of repairs, replacement and inspection decisions (Kelly, 1997). Selection of the best maintenance strategy depends on several factors. The company under study has chosen for Total Productive Maintenance (TPM).

Any type of equipment contains several components or parts which are confronted with planned or unplanned maintenance. Unplanned maintenance refers to random failures of the components or parts. Corrective maintenance is the original maintenance strategy appearing in industry (Waeyenbergh & Pintelon, 2002), where maintenance is done whenever a failure occurs. This strategy is acceptable when the consequence of failure is small. Predictive maintenance is a planned maintenance approach where failures of facilities are avoided. This approach tries to forecast lifetime of equipment and recommends a corrective action. The downtime of equipment can be reduced if the preventive maintenance strategies are correctly selected (Mobley, 2002).

METHODOLOGY

The methodology consists of several steps. The first step collected historical data of parts of a rice cooker from the maintenance department including part name, age and cost. For practical reasons, data collection was limited to a period of two years. Next, the distribution of age using situation analysis was determined. Then, the age of parts of a rice cooker wss evaluated in six scenarios using worst case, best case, average case and simulation model as shown in Table 1.

1. Worst case: If a part has been replaced before two years of age, we use the minimum age before replacement. A part that has never been replaced before two years, an age of two years is used.
2. Best case: If a part has been replaced before two years of age, we use the maximum age before replacement. A part that has never been replaced before two years, the supplier is asked to evaluate the age.
3. Average case 1: If a part has been replaced before two years of age, we use the average age. A part that has never been replaced before two years, the supplier is asked to evaluate the age.
4. Average case 2: To estimate the part age after TPM implementation, a part that has been replaced before two years, the average age of the last two replaecment times is used. A part that has never been replaced before two years, the supplier is asked to evaluate the age.
5. Simulation case 1: A part that has been replaced before two years, the age is simulated by means of a historical age distribution. A part that has never been replaced before two years, the supplier is asked to evaluate the age.
6. Simulation case 2: To estimate the part age after TPM implementation, a part that has been replaced before two years, the age is simulated by means of a historical age distribution but by cutting the lowest age. A part that has never been replaced before two years, the supplier is asked to evaluate the age.

Table 1. Situation Analysis of Part Age

Senarios	Age of rice cooker parts (days)	
	Parts ever be replaced before two years	Parts never be replaced before two years
Worst case (W)	Minimum age	2 years
Best case (B)	Maximum age	Evaluate age by a supplier
Average Case (A1)	Average age	Evaluate age by a supplier
Average Case 2 (A2)	Average age of the last two ages	Evaluate age by a supplier
Simulation 1 (S1)	Distribution of age	Evaluate age by a supplier
Simulation 2 (S2)	Distribution of age after cutting lowest age	Evaluate age by a supplier

In the first four scenarios, the part age was assumed to be constant under different situations. A spreadsheet was used to calculate the number of parts used in a period of ten years. The latter two scenarios, a simulation model was built to mimic the part replacement process of 30 parts of a rice cooker using ARENA software version 14.0. We determined the replacement time or the age of parts based on the age estimated from Table 1. The 'Record' module recorded the number of parts arrivals and the replacement cost was calculated. Thirty replications were run for the period of ten years. Then, the total replacement cost estimation of 6 scenarios were compared with the actual cost. Next, the parts inventory was categorized based on its replacement cost for a two years basis using ABC analysis. It helps the maintenance department to prioritize the thirty parts and determine the right policy for parts replacement. Finally, an appropriate inventory policy of each category was proposed.

RESULTS AND DISCUSSION

Part Life Analysis

Some parts of the rice cooker were replaced before two years. The replacement time indicates the life of the part and the distribution of age was determined from the historical data. Since there was limited historical data of part life, we proposed several scenarios and determined the best scenario to be representative of the current situation. For some parts, only two data points were available and the best distribution determined by input analyzer in ARENA software was a Beta-distribution. On the other hand, other parts have never been replaced before two years. It implied that their lifetimes were more than two years. Hence, we asked the suppliers of parts to estimate the life as a constant of lifetime. The first set of parts had an equal lifetime of 730 days or two years i.e. the motor pump, the mechanical seal, the connecting, the solenoid valve, the free roller in feed, the gear motor, the gear box, and the chain tensioner roller. In Arena, we combined the arrival of these parts in the same 'Entity' with a total cost of 99,213 Baht. Next, the second set of parts contained the feeding transportation roller and the curve roller with a total cost of 10,674 Baht. Their lifetimes from supplier estimation was three years or 1,095 days. The third set contained the main driving pocket, the control box, and the gas burner with a total cost of 257,324 baht and estimated life from supplier was 1,825 days or five years. The other parts had a different replacement interval within two years. We observed that there were many parts that the minimum and maximum lifetimes were very different such as the transportation chain, the support bearing for main driving shaft, the transportation free roller type, the main driving unit, the lid supporting, the belt, the main driving shaft, the lid supporting 1 and 2, the gas connecting, the pressure regulator, the key and the shaft. The reason was that the company starts implementing TPM that can extend the lifetimes of the parts.

Simulation Model

First, the simulation model to estimate the number of part replacements was built. There were thee basic modules: create, record and disposal. First, the arrival contained the interarrival time which implied the life of the parts. Next, the record kept the number of parts replaced in a certain time. Finally, the parts departed from the system. In addition, we established the cost of a part as a variable in variable spreadsheet module. The simulation model was made up in the simulation software ARENA version 14.0 (Kelton et al., 2014).

Table 2. Distributions and parameters of part lifetimes of a rice cooker in six scenarios

Parts	Code	Cost (Baht)	Life of rice cooker parts of Scenario (days)					
			W	B	A1	A2	S1	S2
Motor Pump	M9	25,000	730	730	730	730	730	730
Mechanical Seal	M23	1,700	730	730	730	730	730	730
Connecting	M30	270	730	730	730	730	730	730
Solenoid Valve	M21	2,560	730	730	730	730	730	730
Free Roller In Feed	M12	12,883	730	730	730	730	730	730
Gear Motor	M10	25,000	730	730	730	730	730	730
Gear Box	M11	25,000	730	730	730	730	730	730
Chain Tensioner Roller	M17	6,800	730	730	730	730	730	730
Out Feeding Transportation Roller	M29	367	730	1095	1095	1095	1095	1095
Curve Roller	M13	10,306	730	1095	1095	1095	1095	1095
Main Driving Pocket	M6	72,324	730	1825	1825	1825	1825	1825
Control Box	M4	92,500	730	1825	1825	1825	1825	1825
Gas Burner	M3	92,500	730	1825	1825	1825	1825	1825
Transportation Chain	M18	6,762	34	316	146	316	34 + EXPO(89.8)	235 + 82 * BETA(0.226, 0.238)
Support Bearing for Main Driving Shaft	M20	3,480	23	273	122	221	23 + EXPO(68.4)	49 + 224 * BETA(0.226, 0.238)
Transportation Free Roller Type	M7	68,000	223	507	365	365	223 + EXPO(68.4)	223 + EXPO(68.4)
Main Driving Unit	M5	72,324	10	271	104	215.5	TRIA(10, 55, 160)	62 + 209 * BETA(0.226, 0.238)
Soaking Tank	M1	874,000	730	2555	2555	2555	2555	2555
Lid	M8	49,000	304	426	365	365	304 + 122 * BETA(0.112, 0.112)	304 + 122 * BETA(0.112, 0.112)
Lid Supporting 1	M19	3,897	70	448	243	330	70 + EXPO(173)	70 + EXPO(173)
Belt	M2	102,760	191	539	365	365	191 + 348 * BETA(0.112, 0.112)	191 + 348 * BETA(0.112, 0.112)
Main Driving Shaft	M14	9,000	49	414	183	300	49 + EXPO(134)	49 + EXPO(134)
Lid Supporting 2	M22	2,385	49	310	122	252	20 + EXPO(102)	194 + 116 * BETA(0.226, 0.238)
Gas Connecting	M27	1,440	264	466	365	365	264 + 202 * BETA(0.112, 0.112)	264 + 202 * BETA(0.112, 0.112)
Pressure Regulator	M24	1,530	195	535	730	730	730.00	730.00
Pressure Gauge	M26	1,500	163	388	243	284	163 + WEIB(17.7, 0.262)	163 + WEIB(17.7, 0.262)
Shut Valve	M16	8,610	730	1460	1460	1460	1,460.00	1,460.00
Electric Connecting Terminal	M28	1,440	324	406	365	365	324 + 83 * BETA(0.237, 0.226)	324 + 83 * BETA(0.237, 0.226)
Key	M25	1,530	195	535	365	365	195 + 340 * BETA(0.112, 0.112)	195 + 340 * BETA(0.112, 0.112)
Shaft	M15	9,000	49	580	365	365	150 + 430 * BETA(0.112, 0.112)	150 + 430 * BETA(0.112, 0.112)

Output Analysis

In our analysis (and in the figures in this section), the parts of the rice cooker were coded as M1,..,M30 for simple identification. The cost and the number of parts used in six scenarios were shown in Table 3. The maximum cost was 874,000 baht for soaking tank and the minimum cost was 270 baht for connecting. The total cost of parts for a rice cooker was 1,583,868 baht. The result showed that in the worst case scenario, parts which had a record of replacement by two years were replaced often. This could not happen in the actual system. However, it showed how poor the situation could be. Next, for the best case scenario, the parts were assumed to have the maximum lifetime and were replaced the least. This case represented the lower bound of the budget for the rice cooker replacement. The average case before TPM implementation (A1) represented the past situation quite well, however, the average case after TPM implementation (A2) represented the present situation since the lifetime of parts were lengthened due to proper maintenance. The numbe of parts obtained via the simulation models were the average of 30 replication runs. We oberved that the number of parts used in A1 and S1 and A2 and S2 were very similar since the lifetimes were obtained from the same assumption before and after the TPM implementation. Figure 1 visualized the comparison of the number of parts used in the five scenarios except the worst case since it was an extreme case which outranged the other cases.

Table 3. Total Replacement Cost Estimation of 6 Scenarios

Year	Total Replacement Cost Estimationof Scenario (baht)					
	W	B	A1	A2	S1	S2
1	3,114,364	84,951	504,658	332,518	546,677.97	329,466.10
2	7,734,935	518,212	1,194,542	841,583	1,268,976	890,461
3	10,987,186	929,738	1,709,874	1,259,483.60	1,952,651	1,348,652
4	15,600,994	1,197,789	2,408,368	1,706,335	2,736,293	1,926,244
5	18,974,202	1,787,721	3,172,050	2,385,066	3,638,751	2,638,535
6	23,528,213	2,296,947	3,870,907	2,899,624	4,443,652	3,220,644
7	26,847,024	3,356,937	5,251,265	4,121,969	5,982,532	4,582,738
8	31,457,172	3,730,808	5,949,759	4,639,644	6,780,445	5,127,284
9	34,709,483	4,133,334	6,465,091	5,057,545	7,473,966	5,600,916
10	39,382,951	4,715,219	7,412,299	5,764,507	8,478,095	6,403,187

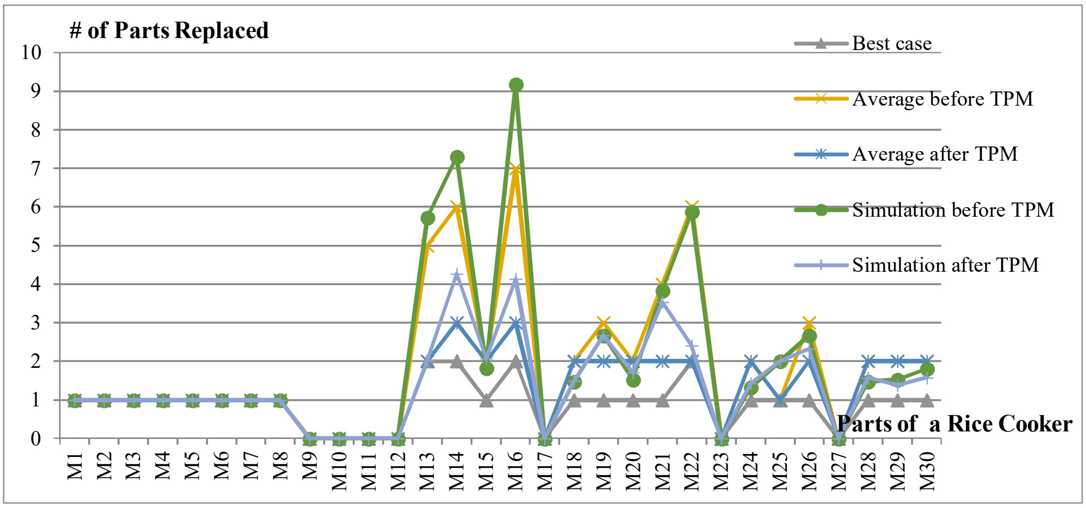

Figure 1. The Estimated Number of Part Used in Six Scenarios for Two Years

The cumulative and average annual replacement costs in a period of 1 to 10 years of six scenarios were shown in Table 3 and Figure 2. This estimation helped the engineering department to determine a strategic budget plan of the rice cooker replacement. The result showed that the replacement cost estimation ranking from the lowest to highest were: (1) best case, (2) average case after TPM implementation, (3) simulation after TPM implementation, (4) average case before TPM implementation, (5) simulation before TPM implementation, and

(6) worst case, respectively. The result seemed to be reasonable since the simulation case included more uncertainty, so the replacement cost was higher than the average case. In addition, it was more economic to replace the parts as fast as possible since the average annual replacement cost estimated showed that the cost was increasing year by year.

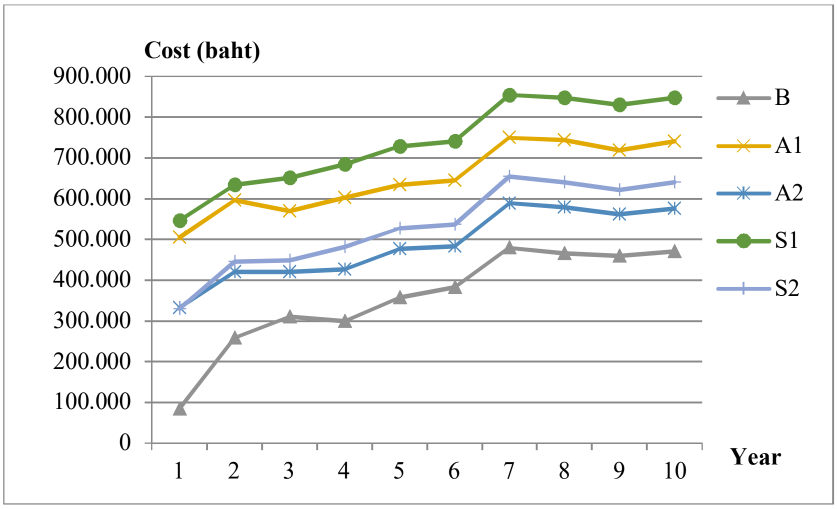

Figure 2. Average Annual Replacement Cost Estimation of Five Scenarios

Part Replacement Cost Comparison

Then, we compared the replacement of rice cooker parts for two years (2009-2010) of six scenarios with the actual cost as shown in Table 4. The actual cost replacement cost for two years was 761,281 baht. The average cost after TPM implementation was the best estimator with 10.55% difference. The simulation after TPM implementation was the second best estimator with 16.97% difference. While the estimators before TPM implementation were poor since the maintenance policy changed. In summary, after TPM implementation, the part life could be estimated by using the average of the recent historical data during TPM implementation. This implied that after TPM implementation, the life of machines or parts are lenghten and the total replacement cost can be reduced.

Table 4. Two-Year Replacement Cost Estimation

Case	Before TPM Implementation		After TPM Implementation	
	Total Replacement Cost (baht)	% Difference	Total Replacement Cost (baht)	% Difference
Worst Case (W)	7,734,935	916.04%	-	-
Best Case (B)	-	-	518,212	-31.93%
Average Case	1,194,542 (A1)	56.91%	**841,583 (A2)**	**10.55%**
Simulation	1,268,976 (S1)	66.69%	890,461 (S2)	16.97%
Actual Cost	-	-	761,281	-

Inventory Control for Spare Parts of the Rice Cooker

Spare parts of the rice cooker will be kept in a store for maintenance or repair. Spare parts for equipment might be expensive and costly to keep in inventory. However, spare parts still need to be kept in inventory to limit equipment unavailability. In case preventive maintenance is implemented, the demand for spare parts appears from two sources: the scheduled maintenance and the demand due to random failures. An ordering policy for this situation is proposed by Vaughan (2005).

In this part, we categorized the parts based on ABC analysis from the estimated replacement cost for two years in six scenarios as in Table 5. The result showed that mainly the types of all thirty parts was almost the same in the A1, A2, S1, S2. The worst and best case scenarios led to slightly different types in some parts. However, we analyzed, based on scenarios A2, which is the best estimator of the replacement. There were parts, of which their lifetime was longer than two years, so they have not been replaced in two years i.e. motor pump, gear motor, gear box, free roller in feed, chain tensioner roller, mechanical seal and gas connecting (M9-M12, M17, M23, and M27). These parts were categorized in type C which implied that the staff could less strict check for the inventory of these types. On the other hand, the parts of type A included the soaking tank, belt, gas burner, control box, and main driving unit which had a high cost, but their lifetimes were about two years. This implied that the staff should strictly inspect these parts. We noticed that, if the staff could raise the life of the shut valve (M16), the replacement cost could be reduced. In addition, we can implement this category interpretation in the maintenance department where the staff should strictly inspect the condition of type A parts and less strict for type B and C, respectively.

Table 5. The Type of Part in Six Scenarios based on ABC Analysis

No.	Index	Scenarios						No.	Index	Scenarios					
		W	B	A1	A2	S1	S2			W	B	A1	A2	S1	S2
1	M1	A	A	A	A	A	A	16	M16	C	B	B	B	A	B
2	M2	A	A	A	A	A	A	17	M17	C	C	C	C	C	C
3	M3	A	A	A	A	A	A	18	M18	C	B	C	C	C	C
4	M4	A	A	A	A	A	A	19	M19	C	B	C	C	C	C
5	M5	A	A	A	A	A	A	20	M20	C	C	C	C	C	C
6	M6	B	B	B	B	B	B	21	M21	C	C	C	C	C	C
7	M7	B	B	B	B	B	B	22	M22	C	B	C	C	C	C
8	M8	B	B	C	B	C	B	23	M23	C	C	C	C	C	C
9	M9	B	C	C	C	C	C	24	M24	C	C	C	C	C	C
10	M10	B	C	C	C	C	C	25	M25	C	C	C	C	C	C
11	M11	B	C	C	C	C	C	26	M26	C	C	C	C	C	C
12	M12	C	C	C	C	C	C	27	M27	C	C	C	C	C	C
13	M13	C	B	C	B	C	C	28	M28	C	C	C	C	C	C
14	M14	C	B	B	B	C	B	29	M29	C	C	C	C	C	C
15	M15	C	B	C	C	C	C	30	M30	C	C	C	C	C	C

CONCLUSION

We estimated the lifetime of parts of an automatic rice cooker and determined when to replace the parts by scenario analysis. We studied the worst cast, best case, average case and simulation for two situations: before and after Total Productive Maintenance (TPM) implementation. The input parameters were the lifetime and cost of parts of a rice cooker. The lifetimes of the parts were random variables according to a probability distribution determined by a simulation software. The output of the simulation was the total maintenance cost of the parts replacement between one and ten years. In other cases, the lifetimes of parts were determined based on a scenario such as minimum, maximum and expected value of lifetimes according to the historical data and supplier data. After TPM implementation, the lifetimes of the machines were lenghtened and the total replacement cost was reduced accordingly and the average case model after TPM implementation was the best estimator. It implied that the TPM implementation was able to lengthen the part life and results in maintenance cost reduction. In addition, the inventory of parts was categorized by means of ABC classification. It helped to allocate the resources to monitor the right parts. In summary, for the company the average case analysis should be implemented to determine when to replace parts and to estimate the maintenance cost of the rice cooker. In the future, this model might be used as a decision support system for investment of different types of machines.

ACKNOWLEDGMENTS

The researchers would like to thank the company who provided us with information. The authors would like to thank a company who provided the information and thanks the graduate school, the Department of Agro Industrial Technology, and the Faculty of Agro-Industry for providing the funding for this conference.

REFERENCES

Buzacott J.A. & L.E. Hanifin (1978). Model of automatic transfer lines with inventory banks: a review and comparison. AIIE Transactions, 10 (2), 197-207.

Hartman J.C. & Tan C.H. (2014). Equipment replacement analysis: a literature review and directions for future research, The Engineering Economist, 59(2), 136-153.

Kelly A. (1997). Maintenance Strategy, Butterworth-Heinemann, Oxford.

Kelton W.D., R. Sadowski & N. Zupick (2014). Simulation with Arena, McGraw Hill, New York.

Kosulwat V. (2002). The nutrition and health transition in Thailand. Public Health Nutrition, 5(1A), 183-189.

Mobley R.K. (2002). An Introduction to Preventive Maintenance, Butterworth-Heinemann, Amsterdam.

Nakajima S. (1988). Introduction to Total Productive Maintenance (TPM), Productivity Press, Cambridge, MA.

Oguchi M., T. Kameya, S. Yagi & K. Urano (2008). Product flow analysis of various consumer durables in Japan. Resources, Conservation and Recycling, 52(3), 463-480.

Park J.L. & O. Capps (2002). Demand for prepared meals by US households. American Journal of Agricultural Economics, 79(3), 814-824.

Sörensen K. & G.K. Janssens (2004). A Petri net model of a continuous flow transfer line with unreliable machines. European Journal of Operational Research, 152(1), 248-262.

Vaughan T.S. (2005). Failure replacement and preventive maintenance spare part ordering policies. European Journal of Operational Research, 161(1), 183-190.

Verheyen P.A. (1979). Economic interpretation of models for the replacement of machines. European Journal of Operational Research, 3(2), 150–156.

Waeyenbergh G. & L.Pintelon (2002). A framework for maintenance concept development. International Journal of Production Economics, 77, 299–313.