# THE INTEGRATION OF SIMPLE MARKOV MODEL IN SOLVING SINGLE LINE PRODUCTION SYSTEM

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# The Integration of Simple Markov Model in Solving Single Line Production System

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*Abstract—* **Small and Medium Enterprise (SME) has limitations in capital to upgrade the production process especially in installing new machines in parallel line. Generally the machines are installed in single-line and not equipped with a modern technology. If any machines in the series are breakdown and stopped, the whole production system also stopped. By understanding the condition, most of SMEs struggle to reduce the overhead cost and increase the company's profit by escalating the availability of the machines. A simple yet powerful Markov model is used in this study to identify the prime cost involves in production line downtimes. The influence of the performance of a single machine on a line is investigated. A case study in the production of the tamarind juice drink, obviously when the failure rate of the machines is reduced, the cost of lost also can be reduced.**

*Keywords-simple markov model; single line production*

## I. Introduction

In numerous studies dealing with production systems, it is assumed that the availability and reliability of the systems are almost perfect. However, in industrial reality, production systems experienced periods of unavailability due to machines breakdown or failure.

All production systems are expected to be operated and worked for the possible maximum time so as to optimize production volumes and profits [1]. But, failure is unavoidable phenomenon as all systems are eventually failed. The widely recognized index used to assess the performance of the systems is a measure of "availability". One of the possible approaches to achieve the high availability and cost-effective operations are through the execution of effective maintenance strategies. The good maintenance management could be able to increase profits in two ways; by decreasing operation cost and increasing capability. Some manufacturer construct production line in parallel in order to increase the production output. However, in the case of SME parallel line is such a constraint due to financial difficulty.

According to [2], Small-scale industry can be defined as those with capital less than RM250, 000.00 and having 5 to 49 workers. While for Medium-scale industry is 50 to 199 workers with capital RM250, 000.00 to one million. Companies beyond that limits are categorized as Large-scale industry. In all countries, SME plays an important role for generating the country's economic growth and also to sustain the global and

regional economic recovery [3]. Although they operate in sn or medium scale, these enterprises have played a v important role to the larger scale industries for their busir needs.

Since SME has limited capital, they are not able to upgr the entire production lines as a whole based in order to enha production process and product's quality. Hence, there are o few machines installed in SME. The production lines in SI are usually consists of machines arranged in series. Machi may experience failure at any time during the product process. An inherent drawback of series system is that if a machine breakdown, the entire line will be stopped maintenance. Having duplicate machines in parallel greatly improve the reliability and availability of the line, this is usually prohibitively expensive. SME has the constr of capital to purchase and install parallel line and stanc systems. Therefore, it is important for them to maintain machines in good condition. A more practical alternative is attempt to prevent machine breakdowns. Thus, they nee proper maintenance to maintain the availability of the machi so that it will reflect the production process.

A simple Markov model was proposed as a technique identifying the costs in production line downtimes and improve the maintenance strategies. This work assumed tha fault on a single machine would stop the production line. purpose of the simple Markov model was to support decisions on equipment maintenance. The maintenance p was proposed for the minimum cost in operating system.

The remainder of this paper is organized as follows. Ot research that used Markov model is presented in Section 2 literature review. In Section 3 is a review on the idealized machine approximation. A simple case study using d obtained from a SME factory that produce tamarind juice dr is presented in Section 4 where the integration of sim Markov model to the production system. The aim is to anal the cost-effectiveness of such increasing the machir availability. In Section 5, the conclusion and future works presented.

## II. Literature Review

Markov models are among the simplest ways of abstract simple concepts into a relatively easily computable for Markov models are widely used in many fields includes so

such as speech signals [4]. Other example is [5] whose study is in television advertising industry where a programming director could decide whether to continue or change certain shows based on the operating costs and expected revenues.

In manufacturing process, one of the studies proposes a Hidden Markov Model to detect machine failure in process control [6]. Other study use an efficient Markov decision process solution to find the best average-cost policy for deterioration machines that pulls the material from the buffer of production line [7]. Other researchers [8] formulated the model as a partially observable Markov decision process to obtain an optimal policy which can minimize the expected total discounted cost over an infinite horizon. The use of Markov state to deal with the production and preventive maintenance control problem for a multiple machine manufacturing systems is also studied [9]. The aim is to find the production and preventive maintenance rate for the machines to minimize the total cost of inventory or backlog, repair and preventive maintenance.

Reference [10] discussed on the states of the system that are not completely observable. In that case, partially observable Markov decision process is used as the solution based on the state probability distributions. Then the states of the system could be estimated by using the reward information obtained via observations. As for [11] stated that a system of a controller can be in two-state when it observes a production system periodically over time. This case used partially observable Markov decision process to maximize the expected discounted value of the total future profits.

The main consideration of this research is a production line consisting of machines working in series. A research on the said scenario compared the analysis using non-linear cost function, based on the distribution of repair time [12]. The simple Markov model is used as a support decisions about equipment maintenance and replacements. While later study suggested that Markov models as a diagnostic tool for the manager who wants an effective way of identifying the prime costs involves in production line downtimes [13].

## III. SIMPLE MARKOV MODEL FOR ONE LINE PRODUCTION

The scenario considers a line consisting of $n$ machines arranged in series. Each of the machines have failure rates or if they build up a buffer, is equivalent to failure rates, $\tilde{\lambda}$. Hence, mean time between failure (MTBF) is $\frac{1}{\tilde{\lambda}}$, $j = 1,2,...,n$. If one machine fails, the production line also fails.

If $\theta_j$ denotes the repair rate for machine $j$, then the mean repair time for the line ($\frac{1}{\theta_j}$) is given by

$$\frac{1}{\theta} = \frac{1}{\lambda} \sum_{j=1}^{n} \frac{\tilde{\lambda}_j}{\theta_j} \tag{1}$$

As an aside it follows the proportion of time that the machine is operative, also known as machine's availability, which is defined by

$$p = \frac{\theta}{(\lambda + \theta)} \tag{2}$$

$b_{in}$ is denoted as the rate of accumulation of items within the buffer of the machines when they are in operative, and $b_{out}$ is the rate of depletion of the items when the machine is under maintenance. $b_{out}$ can be obtained by scaling the production rate for the subsequent machine by the corresponding availability.

The cost incurred when the line fails depend on the downtime of the line and the significance of lost production. The cost per time is not constant but increase with downtime. This is because the longer stoppage incurs additional overhead costs. Furthermore serious faults required special maintenance. The overall cost per shift, $c$ is due to lose in production is then given by

$$c = C_A \times N_A \tag{3}$$

where

$C_A$ = costs of unit production lost on line during failure or maintenance state

$N_A$ = number of units produced from line with no failure or doing maintenance

The value of $c$ provides the information about the performance of the production system and serves as simple measure to quantify good performance of the line. To increase the availability of the lines and reduce the downtime of the lines, it might involve some combination of reducing failure rates and decreasing repair times.

## IV. CASE STUDY FOR TAMARIND JUICE DRINK

A production line survey has been conducted in a small medium enterprise (SME) that produce tamarind juice drink. Sample of the process is shown in Fig. 1.
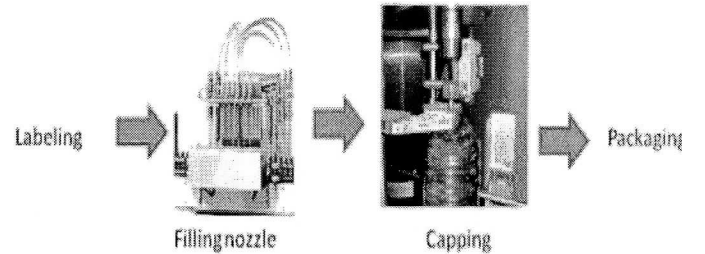


Figure 1. Tamarind Juice Drink Process

Since limited workers and capital used in SME, there only few machines are installed. Most of the machines are connected in a serial line as they have some financial constraints to purchase and install parallel lines and standby system. The machines are fully synchronized and do rely on the immediate supply of units from the previous machine. Therefore, there is no storage of units between the machines, and if any machines in the series is failed, the production system also failed.

The machines of filling nozzle and capping are connected in serial line, as for the filling nozzle machine, it is designed for filling nine bottles simultaneously. In such a set-up, when one of the filling nozzles is failed, the machine needs to stop to undergo repair or do maintenance. While for capping machine, it is designed to do capping only one bottle at one time. In this study, a comparison of production lost when the production output is 2234 bottles per hour and 1107 bottles per hour are shown in Table I and Table II. This output volumes are obtained via observations.

TABLE I.    CASE 1: 2234 BOTTLE PER HOUR

| | Machine | |
|---|---|---|
| | *Filling nozzle* | *Capping* |
| MTBF | 30 | 12 |
| Repair time | 1 | 1 |
| Availability | $\left\{\dfrac{1}{\frac{1}{30}+1}\right\}$ $=0.9677$ | $\left\{\dfrac{1}{\frac{1}{12}+1}\right\}$ $=0.9231$ |
| Production rate when operating per minute | 54 | 43 |
| $b_{in}$ | 2 | - |
| $b_{out}$ | 39 | - |

TABLE II.    CASE 2: 1107 BOTTLE PER HOUR

| | Machine | |
|---|---|---|
| | *Filling nozzle* | *Capping* |
| MTBF | 20 | 20 |
| Repair time | 5 | 10 |
| Availability | $\left\{\dfrac{\frac{1}{5}}{\frac{1}{20}+\frac{1}{5}}\right\}$ $=0.800$ | $\left\{\dfrac{\frac{1}{10}}{\frac{1}{20}+\frac{1}{10}}\right\}$ $=0.667$ |
| Production rate when operating per minute | 45 | 37 |
| $b_{in}$ | 3 | - |
| $b_{out}$ | 24 | - |

The production rate is obtained via observation when the machine is under operation. In Section 3, $b_{out}$ is the scale of production rate and the availability for the subsequent machine. Based on the result of these observations, cost of production per bottle is estimated RM 0.80. The cost of unit production lost during failure or maintenance state, $C_A$ is multiplied with the difference of production rate per minute and the rate of depletion of item when the machine is under maintenance, $b_{out}$. The corresponding values for the cost per unit production lost by using formula (3) is

*Case 1 : (RM 0.80 * (43-39))* 43 =RM 137.60*

*Case 2 : (RM 0.80 *(37-24))*37 =RM 384.80*

From these result it can be seen that the additional cost to recover lost of production from the line for Case 1 is RM 137.60 while for Case 2 is RM 384.80. From these cases, the testing is conducted to measure how sensitive this system in changing the performance. For example in Case 2 the MTBF is increased 50%, then the total cost of recover lost production is reduced from RM 384.80 to RM 296. In addition, if the repair time is reduced by similar amount the cost is further reduced to about RM 236.80. Obviously if the repair rate is reduced then the cost of lost also can be reduced. In other words, it will increase the availability of the machines. When the availability of the line is increased, the production rate will be increasing too. Due to that, the additional cost to recover lost of production from the line can be decreased.

## V.    CONCLUSION AND RECOMMENDATION

In this paper, a simple Markov model is presented to analyze the downtime cost due to production loss. The purpose of the simple Markov model was to support decisions about machines maintenance or replacement. As in our study, the production system is designed in a serial line and the machines are synchronized and do rely on the previous machine. The idealized failure rates allow the application of the simple Markov model to estimate the cost of lost due to failure or repair time of the line. This will lead to the company to decide the maintenance strategies for the production system. By deciding the right maintenance strategies, it may increase the availability of the machines, and yet increase the production output. Furthermore it also could increase the company's profit. As the filling nozzle machine is designed for filling nine bottles simultaneously, the future direction of this study is to identify when is the best time for filling nozzle machine to undergo maintenance. This is because if only one or two of the filling nozzles are failed, the production output may not be affected. By comparing the production lost with the machine stoppage (by doing maintenance) and when the production run with $n$ filling nozzles failed, the significant result could be achieved.

REFERENCES

[1]  A Sachdeva, D. Kumar and P. Kumar, "Planning and optimizing the maintenance of paper production systems in a paper plant." Computers & Industrial Engineering, vol. 55, Issue 4, pp. 817-829, 2008.

[2]  M.K. Ghani, Rural-Based Food Processing Industry, Asian Productivity Organization Report, Japan, 2004.

[3]  A. Shamsuddin, H. Masjuki and T. Zahari, "State of implementation of TPM in SMIs: a survey study in Malaysia", Journal of Quality in Maintenance Engineering, vol. 10 , issue 2, pp.93 – 106, 2004.

[4]  Q. Miao and V. Makis, "Condition monitoring and classification of rotating machinery using wavelets and hidden Markov models" Mechanical Systems and Signal Processing, vol. 21, issue 2, pp. 840-855, February 2007.

[5] M Givon, "Using partially observed Markov processes to select optimal termination time of TV shows", Omega, vol. 36, issue 3, pp. 477-485, 2008.

[6] A.H. Tai, W.K. Ching and L.Y. Chan, "Detection of machine failure: Hidden Markov Model approach" Journal Computers and Industrial Engineering, vol. 57, issue 2, pp. 608-619, September 2009.

[7] A. Pavitsos and E. G. Kyriakidis, "Markov decision models for the optimal maintenance of a production unit with an upstream buffer." Computers & OR, vol. 36, no. 6, pp. 1993-2006, 2009.

[8] J. Lu, T. Mashita and K. Suzuki, "An optimal policy for partially observable Markov decision processes with non-independent monitors", Journal of Quality in Maintenance Engineering, vol. 11, issue 3, pp. 228 – 238, 2005.

[9] A. Gharbi and J.P. Kenné, "Maintenance scheduling and production control of multiple - machine manufacturing systems", Computer and Industrial, vol. 48, issue 4, pp. 693-707, June 2005

[10] X. R. Cao, "Basic ideas for event-based optimization of markov systems" journal discrete event dynamic systems", vol. 15, issue 2, pp. 169-197, June 2005.

[11] G.N. Abraham, "A two-state partially observable markov decision process with uniformly distributed observations", Operations Research. vol. 44, no. 3, pp. 458 - 463. ,June 1996.

[12] D.A. Green, A.V. Metcalfe and D.C. Swailes, "A matrix analytic model for machine maintenance", Matrix-Analytic Methods: Theory and Applications. Guy Latouche and Peter Taylor (Editors), World Scientific publishers, pp. 133-146, 2002.

[13] K. Al-Hassan, D.C. Swailes, J.F.L. Chan and A.V. Metcalfe, "Supporting maintenance strategies using Markov models", IMA J. Management Math , vol 13, no. 1, pp. 17-27, 2002.