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PERFORMANCE OPTIMIZING OF A SANITARY TOWEL PRODUCTION PLANT USING RELIABILITY MODEL

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Abstract

The study was conducted in a firm that manufactures sanitary pads and babies disposable towels which production is below the installed capacity as a result of high production downtime that resulted from incessant breakdown of the subsystems of the production system. The aim of the study was to reduce the production downtime significantly, thereby optimizing the machine time, and consequently, raising the reliability of the production system. The research work obtained machine breakdown records from the production unit and used the data to estimate the reliability of the production system to be 0.708. This showed that the production system was idle for about 30% of the total machine time, thereby incurring a huge production loss. The hazard rates of vital subsystems obtained, as well as the provision of redundancy for some subsystem as appropriate helped to determine the improved reliability of the production system to be 0.862. The study concludes that reliability model could be an effective tool in performance optimization of a production system.

Keywords: production system, downtime, reliability, maintenance, redundancy, hazard rate

1. Introduction

The fundamental objective of any manufacturing organization is to make and maximize profit by overcoming operational challenges, breaking even and realizing desired goals [1]. There are several industrial challenges in Nigeria; prominent among these is the erratic electricity supply, technical gap between industries and researchers, etc. Almost all the industries in Nigeria generate the power they need, which in no small measure raises the cost of production [2]. It is therefore important that the industries run reliable production systems that will ensure continuous production, within the period that the industries generate power. This study was carried out in a firm with high production downtime. The firm manufactures sanitary pads and babies disposable towel. The main aim of this study is to determine the vital subsystems of the production system that are responsible for the bulk of the machine downtime so as to proffer appropriate remedial action plan that will improve its reliability and consequently improve the revenue yield.

A number of performance optimization techniques have been developed for manufacturing systems. Opportunistic maintenance (OM) system was described and used in [3]. It is a systematic method of collecting, investigating, preplanning, and publishing a set of proposed maintenance tasks and acting on them when there is an unscheduled failure or repair "opportunity". In this strategy, preventive maintenance activities are combined with corrective ones as soon as a certain technical and economical conditions are satisfied. In [4], it was suggested that transfer function (TF) modeling as a veritable control theory tool for error minimization in different areas of endeavours in manufacturing, especially in maintenance with the primary goal of minimizing wastes. Failure root cause analysis was presented in [5] as a tool that has optimal solution to maintenance problem and as well solving other industrial related problems. Reliability-centered maintenance was discussed by [6] as a structured framework for analyzing the functions and po-

Table 1: Downtimes of the subsystems of the production system at a given time interval (Hrs).

Time interval Δt (hrs)	Tissue Spreader	Pre-cutter	Base Manifold	Glue Discharger I	Glue Discharger II	Absorbent Discharger	Outer sheet Spreader	Cutter	Burner Unit	Compressor Unit	Power Switch-over	Total Downtime (hrs)
0-100	1.65	1.67	1.75	0	0	3.67	1.63	1.33	1.38	0	2.24	15.32
101-200	1.87	2.73	1.92	0	0	4.25	1.75	1.91	1.83	0	2.33	18.59
201-300	2.72	4.63	2.08	1.82	0	3.55	2.15	3.74	4.23	0	1.67	26.59
301-400	2.9	5.23	2.25	0	0	3.9	2.75	4.82	5.65	54.25	2.5	84.25
401-500	3.15	5.82	2.5	0	1.92	4.43	3.25	5.63	7.84	0	2.33	36.87
501-600	3.92	6.15	3.07	0	0	4.15	3.33	6.55	11.33	0	2.15	40.65
601-700	3.75	6.23	3	0	0	4.24	3.15	6.32	8.92	0	1.67	37.28
701-800	1.2	1.55	1.25	0	0	3.87	1.25	1.15	1.74	0	2.33	14.34
801-900	1.55	1.83	1.3	0	0	4.45	1.83	1.37	3.5	0	2.83	18.66
901-1000	2.35	3.95	1.95	1.75	0	3.87	2.25	3.52	6.23	0	1.33	27.2
1001 - 1100	2.87	4.24	2.85	0	1.67	3.75	2.92	3.91	10.54	0	2.83	35.58
1101 - 1200	3.33	7.25	3.15	0	0	4.15	3.33	6.24	12.83	0	1.67	41.95
1201 - 1300	3.9	7.55	3.45	0	0	4.9	3.45	6.85	15.83	0	2.33	48.26
1301 - 1400	1.15	1.18	1.05	0	0	5.23	1.35	1.38	1.25	0	4.33	16.92
1401 - 1500	1.35	1.19	1.85	0	0	4.75	1.82	1.43	1.75	0	1.33	15.47
1501 - 1600	1.75	2.7	2.3	0	0	3.23	1.95	2.33	3.25	0	2.83	20.34
1601 - 1700	2.23	3.33	3.3	0	1.5	3.87	2.8	2.83	5.53	0	2.33	27.72
1701 - 1800	2.58	3.92	3.45	0	0	4.15	3.56	4.41	8.25	0	1.67	31.99
1801 - 1900	2.8	6.23	3.92	1.85	0	4.33	3.9	5.62	11.75	0	1.76	42.16
1901 - 2000	3.3	6.54	3.7	0	0	4.83	3.3	5.25	9.54	0	2.83	39.29
2001 - 2100	1.2	1.15	1.25	0	0	5.65	1.35	1.33	1.13	0	3.67	16.73
2101 - 2200	1.25	1.83	1.38	0	0	4.27	1.42	2.13	1.48	0	2.33	16.09
2201 - 2300	1.38	2.83	1.95	0	1.83	3.64	1.95	3.33	2.53	77.75	1.67	98.86
2301 - 2400	1.45	3.25	2.33	1.93	0	3.91	2.55	4.57	4.75	0	2.83	27.57
2401 - 2500	2.25	4.73	2.95	0	0	3.22	2.83	5.81	9.25	0	2.35	33.39
2501 - 2600	2.65	7.33	3.15	0	0	4.68	3.56	6.25	13.55	0	2.24	43.41
Total	60.5	105.04	63.1	7.35	6.92	108.94	65.38	100.01	165.86	132	60.38	875.48

tential failures for physical asset, such as manufacturing line, with a focus on preserving system functions rather than preserving the equipment. However these techniques did not provide numerical evaluation of performance of production system as reliability model.

The aims of the study are to estimate in numerical term, the performance of the firm using reliability model; reduce the downtime to the acceptable minimum as described in [7]; improve the performance of the production system; estimate the numerical value associated with the improvement and determine the monetary worth of the production loss for the period of 18 weeks of the study.

2. Materials and Methods

The study obtained the details of the machine breakdown from the maintenance record of the production unit. The record contained the duration of breakdown of all the subsystems that make up the production system. The firm policy mandated all such breakdowns to be recorded correctly and ensured strict compliance. This made the data obtained dependable for the study.

The firm under study runs three shifts per day and operates every day except on Sundays. General routine maintenance was carried out once in a month. The duration of the study spanned a period of 18 weeks, a total of 108 working days, amounting to 2592 working hours. Ten subsystems in the production system were identified with various degrees of significant machine downtime. However,the first six in the breakdown hierarchy were considered in the improvement plan.This was so done because the reliability schools of thought suggested that remedial efforts should be directed at the vital parts [8].

2.1. Development of reliability and hazard model

According to [1 & 9], if it is assumed that there are N components in a system at the commencement of operations at time $t = 0$, as the time progresses, the components begin to fail. After a given time t, assuming that the number of surviving components are denoted $N_s(t)$, the reliability of the system is defined as:

$$R(t) = \frac{N_s(t)}{N} \tag{1}$$

Similarly, the hazard rate, a measure of instantaneous speed of failure is defined in [3] as:

$$Z(t) = \frac{N_s(t) - N_s(t+\Delta t)}{N_s(t)\Delta t} \tag{2}$$

In differential form

$$Z(t) = \frac{1}{N_s(t)} \left(\frac{-dN_s(t)}{dt} \right) \tag{3}$$

Differentiating equation 4 with respect to time, t

$$\frac{dR(t)}{dt} = \frac{1}{N} * \frac{dN_s(t)}{dt} \left\{ \text{or } \frac{dR(t)}{dt} = \frac{1}{N} * \frac{dN_s(t)}{dt} * \frac{-N}{-N_s(t)} \right\} \tag{4}$$

Substitute equation 3 into equation 4

$$\frac{dR(t)}{dt} = \frac{-N_s(t)}{N} * Z(t) \tag{5}$$

Comparing equations 5 and 1

$$\frac{dR(t)}{dt} = -R(t) * Z(t) \left\{ \text{or } -Z(t)dt = \frac{dR(t)}{R(t)} \right\} \tag{6}$$

Integrating both the sides of equation 6 from $t = 0$ to time t,

$$-\int_0^t Z(t)dt = \int \frac{dR(t)}{R(t)} \tag{7}$$

$$-\int_0^t Z(t)dt = \log_e R(t) \tag{8}$$

$$R(t) = \exp\left[-\int_0^t Z(t)dt \right] \tag{9}$$

For a single subsystem with independent failure [10],

$$Z(t) = \frac{\text{time of failure}}{N_s(t) \cdot \Delta t} \tag{10}$$

$N_s(t)$ would be a unit value(the subsystem involved), while Δt would be the total machine time.

Similarly, the reliability of a single subsystem that is put back to work through repair is defined in [10] as the ratio of the uptime of the subsystem to the total operation time.

$$R = \frac{\text{Machine time} - \text{Downtime}}{\text{Machine time}} \tag{11}$$

$$R = \frac{\text{Uptime}}{\text{Machine time}} \tag{12}$$

From the data containing the failure records from the production floor, the reliabilities of the subsystems were obtained individually using equation 11. These values were substituted into equation 10 to estimate the hazard rate of each equipment. The hazard rate of each of these subsystems was substituted into the general reliability model in equation 9. The result showed a very high correlation with the individual reliability. This makes the model an appropriate tool for performance improvement.

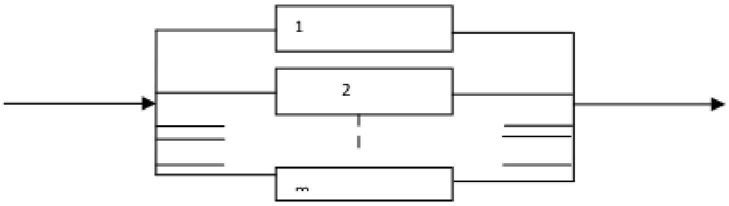

Figure 1: Parallel components.

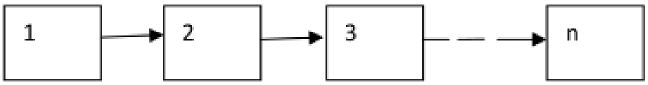

Figure 2: Components in series.

2.2. Systems with parallel components

A system is said to have its components in parallel if and only if the successful functioning of any one of the components leads to the success of the system [1, 11]. A system with m-components in parallel could be represented as shown in fig 1.

The system reliability is given as

$$R = Pr(E_1 \cup E_2 \ldots \cup E_m) \tag{13}$$

Expressing the reliability as a function of time,

$$R(t) = 1 - \prod_{1=1}^{m} q_i(t) \tag{14}$$

But $p_i(t) + q_i(t) = 1$. Therefore,

$$R(t) = 1 - \prod_{1=1}^{m} [1 - p_i(t)] \tag{15}$$

Where $p_i(t) = Pr(E_i)$ and $q_i(t) = Pr(\overline{E}_i)$ i.e. probability of success and failure respectively.

If the components have the same probability of success (same reliability), then the system reliability becomes;

$$R(t) = 1 - [1 - P(t)]^m \tag{16}$$

Provision of redundancy for any system or subsystem is premised on this model, given in equation 16. It is also on this basis that redundancy is provided for the subsystems in this work.

2.3. System with components in series

A system is said to have components in series if the successful operation of the system depends upon the proper operation of all the n components in the system [1, 11] System with components in series could be represented as shown in fig. 2.

If E_i denotes the event that component i functions satisfactorily and $\overline{E}_i$ denotes the event that the

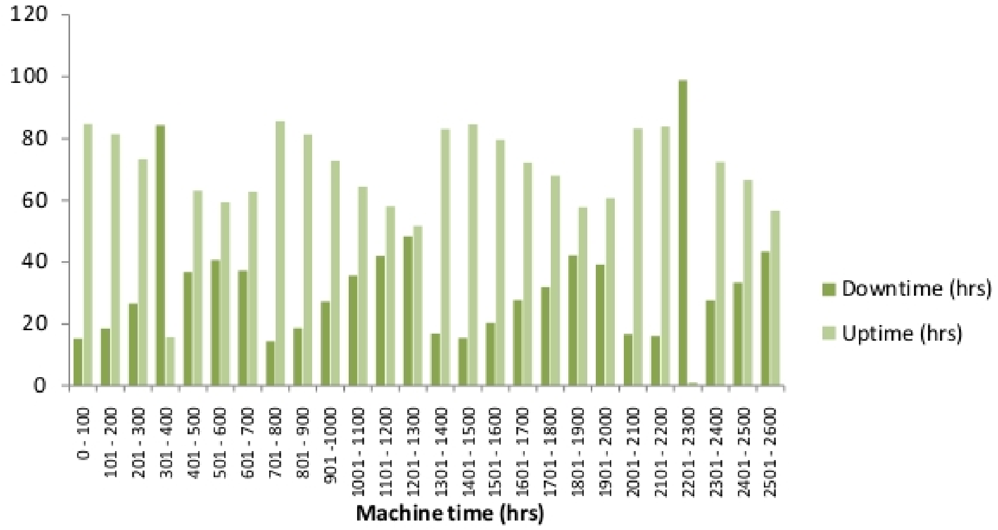

Figure 3: Relationship between downtime and uptime (hrs).

Table 2: Percentage composition of Downtimes (by hierarchy).

Subsystems	Downtime (hrs)	% of Total downtime
Burner Unit	60.5	6.91
Compressor Unit	132	15.08
Absorbent discharger	108.94	12.44
Pre-cutter	105.04	12.44
Cutter	100.01	11.43
Outersheet spreader	65.38	7.47
Base manifold	63.1	7.2
Tissue spreader	60.5	6.91
Power switch-over	60.38	6.9
Glue discharger I	7.35	0.84
Glue discharger II	6.92	0.79

component does not function satisfactorily (or fails), from the laws of probability, the reliability of the system success is the intersection of, E_1, E_2, E_3, $\ldots$, E_n. The system reliability could be expressed as:

$$R = P(E_1 \cap E_2 \cap E_3 \ldots \cap E_n) \tag{17}$$

$$\begin{aligned} R = P(E_1) * Pr(E_2/E_1) * Pr(E_3/E_1E_2) * \cdots \\ *Pr(E_n/E_1E_2 \ldots E_{n-2}E_{n-1}) \end{aligned} \tag{18}$$

$Pr(E_3/E_1E_2)$ is a conditional probability which means the probability of events 3 given the events 1 and 2 have occurred. However, if the components are independent, then

$$R = P(E_1) * Pr(E_2) * Pr(E_3) * \cdots * Pr(E_n) \tag{19}$$

Equation 19 is important in estimating the reliability of the entire production system, before and after improvement. This is based on the fact that the subsystems of the production system are in series.

3. Results and Discussion

The durations of breakdown for each subsystem were collated in 100 hours that the production system was supposed to work (the machine time). The summary of the downtimes of each of the subsystems in every 100 hours of machine time is given in table 1. It is from this table that the failure distributions of the subsystems were obtained. This enabled the study to determine the availability of each subsystem in every 100hours of machine time. It could also help to determine if system failure was peculiar to a particular time of operation and/or particular set of production personnel. The table also revealed the production downtime within the total machine time of 2592 hours that the research work covered. This enabled the study to determine the reliability of production system using the available time (the gross revenue associated with the available time of the production system could also be estimated). Fig 3 is a bar chart indicating the downtimes and the uptimes in the intervals of 100 hours of machine time. The magnitude of downtime necessitated remedial efforts that would increase the availability of the production system.

Table 2 shows the summation of the downtimes for each of the subsystems in decreasing order, and its percentage composition of the total downtime. It helped to estimate the contribution of each subsystem to the total production downtime. This enabled the study to determine the most critical subsystems that required performance improvement efforts. Table 3 provides the hazard rate (a measure of the speed of failures) of the subsystems.

Table 3: Hazard rates of the critical subsystems.

Time Interval Δt (hrs)	Tissue spreader		Pre-cutter		Base manifold		Outersheet spreader		Cutter		Burner		
	Rel	HR	Rel	HR	Rel	HR	Rel	HR	Rel	HR	DT	Rel	HR
0-100	0.9835	0.0165	0.9833	0.0167	0.9825	0.0175	0.9837	0.0163	0.9867	0.0133	1.38	0.9862	0.0138
101-200	0.9813	0.0187	0.9727	0.0273	0.9808	0.0192	0.9825	0.0175	0.9809	0.0191	1.83	0.9817	0.0183
201-300	0.9728	0.0272	0.9537	0.0463	0.9792	0.0208	0.9785	0.0215	0.9626	0.0374	4.23	0.9577	0.0423
301-400	0.971	0.029	0.9477	0.0523	0.9775	0.0225	0.9725	0.0275	0.9518	0.0482	5.65	0.9435	0.0565
401-500	0.9685	0.0315	0.9418	0.0582	0.975	0.025	0.9675	0.0325	0.9437	0.0563	7.84	0.9216	0.0784
501-600	0.9608	0.0392	0.9385	0.0615	0.9693	0.0307	0.9667	0.0333	0.9345	0.0655	11.33	0.8867	0.1133
601-700	0.9625	0.0375	0.9377	0.0623	0.97	0.03	0.9685	0.0315	0.9368	0.0632	8.92	0.9108	0.0892
701-800	0.988	0.012	0.9845	0.0155	0.9875	0.0125	0.9875	0.0125	0.9885	0.0115	1.74	0.9826	0.0174
801-900	0.9845	0.0155	0.9817	0.0183	0.987	0.013	0.9817	0.0183	0.9863	0.0137	3.5	0.965	0.035
901-1000	0.9765	0.0235	0.9605	0.0395	0.9805	0.0195	0.9775	0.0225	0.9648	0.0352	6.23	0.9377	0.0623
1001-1100	0.9713	0.0287	0.9576	0.0424	0.9715	0.0285	0.9708	0.0292	0.9609	0.0391	10.54	0.8946	0.1054
1101-1200	0.9667	0.0333	0.9275	0.0725	0.9685	0.0315	0.9667	0.0333	0.9376	0.0624	12.83	0.8717	0.1283
1201-1300	0.961	0.039	0.9245	0.0755	0.9655	0.0345	0.9655	0.0345	0.9315	0.0685	15.83	0.8417	0.1583
1301-1400	0.9885	0.0115	0.9882	0.0118	0.9895	0.0105	0.9865	0.0135	0.9862	0.0138	1.25	0.9875	0.0125
1401-1500	0.9865	0.0135	0.9881	0.0119	0.9815	0.0185	0.9818	0.0182	0.9857	0.0143	1.75	0.9825	0.0175
1501-1600	0.9825	0.0175	0.973	0.027	0.977	0.023	0.9805	0.0195	0.9767	0.0233	3.25	0.9675	0.0325
1601-1700	0.9777	0.0223	0.9667	0.0333	0.967	0.033	0.972	0.028	0.9717	0.0283	5.53	0.9447	0.0553
1701-1800	0.9742	0.0258	0.9608	0.0392	0.9655	0.0345	0.9644	0.0356	0.9559	0.0441	8.25	0.9175	0.0825
1801-1900	0.972	0.028	0.9377	0.0623	0.9608	0.0392	0.961	0.039	0.9438	0.0562	11.75	0.8825	0.1175
1901-2000	0.967	0.033	0.9346	0.0654	0.963	0.037	0.967	0.033	0.9475	0.0525	9.54	0.9046	0.0954
2001-2100	0.988	0.012	0.9885	0.0115	0.9875	0.0125	0.9865	0.0135	0.9867	0.0133	1.13	0.9887	0.0113
2101-2200	0.9875	0.0125	0.9817	0.0183	0.9862	0.0138	0.9858	0.0142	0.9787	0.0213	1.48	0.9852	0.0148
2201-2300	0.9862	0.0138	0.9717	0.0283	0.9805	0.0195	0.9805	0.0195	0.9667	0.0333	2.53	0.9747	0.0253
2301-2400	0.9855	0.0145	0.9675	0.0325	0.9767	0.0233	0.9745	0.0255	0.9543	0.0457	4.75	0.9525	0.0475
2401-2500	0.9775	0.0225	0.9527	0.0473	0.9705	0.0295	0.9717	0.0283	0.9419	0.0581	9.25	0.9075	0.0925
2501-2600	0.9735	0.0265	0.9267	0.0733	0.9685	0.0315	0.9644	0.0356	0.9375	0.0625	13.55	0.8645	0.1355

DT = Downtime; Rel = Reliability; HR = Hazard rate

3.1. Estimation of reliability of the production system

From equation 19, the reliability of the system with components in series, when the components failures are independent is:

$$R(t) = Pr(E_1) * Pr(E_2) * Pr(E_3) * \cdots * Pr(E_n)$$

Therefore, the reliability of the system is:
R(System) = R(Tissue Spreader) * R(Pre-cutter) * R(Base Manifold) * R(Discharger l) * R(Discharger ll) * R(Absorbent)*R(Outersheet)* R(Cutter) *R(Ends Sealer) * R(Compressor)*R(Power Change Over). Using equation 11, the reliability of each subsystem could be obtained as follows:

Using equation 11, the reliabilities of the subsystems are obtained and presented in Table 4.

Therefore, the reliability of the entire production system could be estimated as:

$$R(System) = 0.977 * 0.959 * 0.976 * 0.997 * 0.997* \\ 0.958 * 0.975 * 0.961 * 0.936 * 0.949 * 0.977 = 0.708 \quad (20)$$

This reliability of 0.708 means that the production system was operating for about 70.8% of the total machine time. The implication is that out of the machine time of 2592 hours that the study covered, the production system was idle for about 757 hours.

3.2. Confirmation of the reliability equation

The hazard rate was determined for the entire machine time of the single equipment or subsystem. This is due to the fact that there were variations in the intervals of equipment failure. The value of the hazard rate was interpreted as the failure per hour within the entire machine time. The hazard rate was expressed in equation 10, while the reliability was expressed as a function of the hazard rate in equation 9.

The reliability of the vital subsystems obtained using their hazard rates are presented in table 5. These reliability values obtained from the hazard rates of the subsystems correspond to the reliability values of the subsystem obtained original. This fact confirms that the system reliability originally estimated is valid and the hazard rates of the subsystems could be used for improvement planning.

3.3. Improvement of the subsystems

3.3.1. Improvement of the ends sealer

This subsystem is responsible for the 'sealing' of the end products. Its main components are heating elements. However, from Table 2 and Figure 3, the significant rise of the hazard rate of this unit could be observed. The unit however is not complex and could be easily dismantled and replaced. R(Burner) = 0.936 (as obtained).

Table 4: Reliabilities of the subsystems.

	Subsystems	Reliability
1	Tissue Spreader	0.977
2	Pre-Cutter/Separator	0.959
3	Base Manifold	0.976
4	Discharger I	0.997
5	Discharger II	0.997
6	Absorbent Discharger	0.958
7	Outersheet Spreader	0.975
8	Cutter/Separator	0.961
9	Burner Unit	0.936
10	Compressor Unit	0.949
11	Power Change-over	0.977

Table 5: Reliabilities of Vital Subsystem using hazard model.

	Subsystems	Reliability
1	Burner Unit	0.938
2	Compressor Unit	0.95
3	Absorbent Discharger	0.958
4	Pre-cutter/Separator	0.96
5	Cutter/Separator	0.962
6	Outersheet Spreader	0.975

$R(Burner) = 3p - 3p^2 + p^3 = 0.9997$

In order to effect the improvement of the reliabilities of the vital subsystems, the downtimes, the failure distributions and hazard rate of these subsystems were taken into consideration.

3.3.2. Improvement of the compressor unit

The operations of the discharge units are all pneumatics. They all depend solely on the effectiveness of the compressor. The compressor unit did not breakdown often, but when it failed, there was a significant effect on the production system. A feasible solution is the provision of redundancy such that when a unit fails, the other could salvage systemic failure.

R(Compressor) = 0.949 (as obtained)
$R(Compressor\ Unit) = 2p - p^2 = 2(0.949) - 0.949^2 = 0.997$

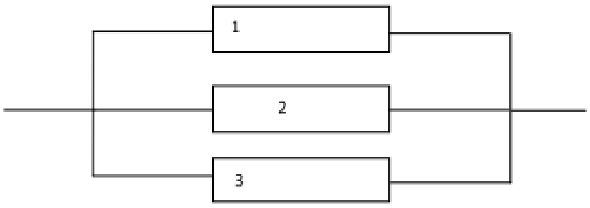

Figure 4: Provision of reducdancy for Ends Sealer Unit.

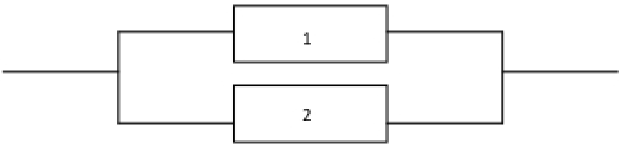

Figure 5: Provision of redundancy for the Compressor Unit.

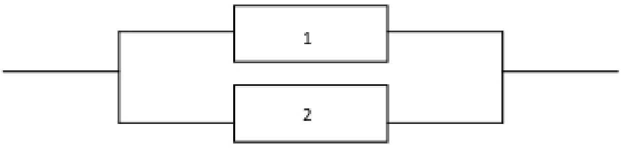

Figure 6: Provision of redundancy for the Absorbent Discharger.

3.3.3. Improvement of absorbent discharger

This subsystem contains a fluid that is sprayed of the surface of the end products to aid its liquid absorption. However, its content is exhausted with continuous production and it is to be refilled. The performance of this unit is largely dependent upon the expertise of the operator. On a more technical note, provision of redundancy for this unit as shown in fig. 5 will have a significant impact on the reliability of the production system. As obtained earlier, R(Absorbent Discharger) = 0.958.

$R(Absorbent\ Discharger) = 2p - p^2 = 2(0.958) - 0.958^2 = 0.998$

3.3.4. Improvement of the pre-cutter/separator

Tables 1, 3 and figure 3 show the data relating to this subsystem. The hazard rate of this unit is 0.0405 for the entire operation time of 2592hours.This means that this unit is responsible for a downtime of 0.0405hour in every hour of operation. In other words, it is responsible for 105hours (0.0405 x 2592) of downtime within the machine time. However, from table 1, it is noted that the monthly routine maintenance took place after time 648, 1296, 1944 and 2592 hours. Table 2 shows that the hazard rate increases within these time intervals.

The reliability of this subsystem could be improved if preventive maintenance is performed on this unit as the hazard rate tends to rise significantly, say 0.025 at 200hours of operation. The action taken may include sharpening and adjusting the cutting knife, re-aligning the separating edges, etc. The improved reliability is obtained using equation 2.15 and presented in table 6. This is an improvement of the reliability of this unit from 0.959 to 0.975.

Table 6: Improved Reliabilities of the Vital Subsystems.

	Subsystems	Reliability
1	Burner Unit	0.9997
2	Compressor Unit	0.997
3	Absorbent Discharger	0.998
4	Pre-cutter/Separator	0.975
5	Cutter/Separator	0.98
6	Outersheet Spreader	0.979

3.3.5. Improvement of the cutter/separator

Similarly, tables 1, 3 and figure 3 highlight the performance of this subsystem. It could be seen that the rate of its failure largely increases after 200 hours of operation. It is very important to give attention to this unit after every 200 hours of operation. Its hazard rate of 0.0386 for the machine time of 2592 hours means that the unit is responsible for the downtime of 100hours, i.e. (0.0386 x 2592) for the total machine time. Also from table 3, it is noted that the reliability of this unit could be improved if it is maintained as the hazard rate increases, say at 0.02 after 200hours of operation. The corresponding reliability obtained using equation 2.15 is contained in table 6. This shows an improvement in the reliability of this Subsystem from 0.961 to 0.98.

3.3.6. Improvement of the outersheet spreader

Table 3 shows a steady increase in its hazard rate. The reliability of this subsystem could also be improved if it is maintained after every 300hours of operation when the hazard rate is about 0.0215. The reliability of this improvement is obtained using equation 2.15 and presented in table 6.

3.4. Estimation of the improved reliability of the system

The reliability of the entire production system will be improved with the improvement in the reliability of the subsystems that are responsible for the bulk of the production downtime. The improved reliability could be estimated as:

R(System) = R(Tissue Spreader) * R(Pre cutter) * R(Base Manifold) * R(Discharger I Unit) * R(Discharger II Unit) * R(Absorbent Unit) * R(Outersheet Spreader) * R(Cutter) * R(Burner) * R(Compressor Unit) * R(Power Change Over)

R(System) = 0.977 * 0.975 * 0.976 * 0.997 * 0.997 * 0.998 * 0.979 * 0.98 * 0.9997 * 0.997 * 0.977 = 0.862

3.5. Implication of the improved reliability

If it is assumed that in 1hour operation, the gross revenue accruable to the firm from the sales of its products is \$1500. The savings from the improved reliability could be estimated as follows:

A reliability of 1.0 corresponds to machine time of 2592 hours. i.e. $1.0 \equiv 2592$ hours, therefore, $0.708 \equiv 2592 * 0.708 \equiv 1835.136$ hours. Similarly, $0.862 \equiv 2592 * 0.862 \equiv 2234.304$ hours.

Time savings = 2234.304 - 1835.136 = 339.168 hours.

Equivalent revenue = \$1500 × 339.168 = \$508,752.

This amount represents additional gross revenue accruable to this firm for the 18weeks the study covered, if the improvement is made. The savings would be enormous over a longer duration.

4. Conclusion

This study has been able to determine the level of performance of a production system in quantitative term using reliability model. This revealed the extent of the production loss which made remedial efforts inevitable. The production downtimes have been significantly reduced and the performance of the production system improved, using reliability model. It also estimated the monetary value of the production loss to serve as an eye opener to the business owners so as to engage the services of an industrial professional. The study showed that reliability model is a powerful tool that could be used to improve the performance of a production system, if properly applied.

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