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Assessment of effectiveness and utilization of printing machines

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Abstract

Maintenance has become increasingly important in the production planning and management strategies of some companies. Overall equipment effectiveness is widely used for performance indicator in manufacturing industries around the world. Print productions are also not apart from problems related to the effectiveness of the machines/equipment caused by the six big losses like breakdown losses, setup and adjustment losses, idle and minor stoppage losses, reduced speed losses, process defect losses and reduced yield losses. This can be seen with the frequency of failures that occurs in the machines because of several types of downtime so that the production target is not achieved. Total productive maintenance is the best method that can be used to improve the productivity and efficiency of the plant productions by using the machine effectively. Print production largely depends on the reliability, availability and maintainability of sophisticated printing machines. Aim of the present study is to determine quantitatively overall effectiveness and utilization of some printing equipment. The results of the effectiveness of web-offset printing machine and other ancillary equipment like computer-to-plate (CTP) machines and exposure unit are found to be below 'world standard' value of 85 %. The cause of low effectiveness value was due to poor performance and availability of the machines. Equipment utilization is also needed for the evaluation of printing equipment necessity, appropriateness and efficiency of the usage in print production. The proposed methodology may be able to increase the amount of working printing equipment by implementing proper maintenance planning. A significant increment of OEE (2.93 %) for web-offset printing machine is observed after implementation of proposed maintenance planning. The methodology is also validated by failure probability and reliability of the machines.

Keywords: overall equipment effectiveness (OEE), availability ratio, performance ratio, quality ratio, overall equipment losses (OEL)

1. Introduction

In manufacturing industry, production decisions and its maintenance actions are taken on the basis of daily production output, production speed, production losses, etc., to reach the maximum level of client's satisfaction. The number of failures, downtime associated with breakdown, make ready time, and loss of production are the major problem in print production house.

A common issue in modern printing press is to maintain the availability and reliability of machine. If effective management of printing equipment maintenance is applied then overall effectiveness of equipment can be increased. Overall equipment effectiveness (OEE) is a way to measure the efficiency of any costly equipment as it is the key performance indicator for implementation of total productive maintenance (TPM) philosophy. The primary stages of assessing OEE are implemented by measurement of availability loss, performance loss and quality loss.

Total effective equipment performance (TEEP) is a performance metric that takes account for both effectiveness in terms of equipment losses and utilization in terms of schedule losses. The workflow management of press is also concerned with the utilizations of printing machines, particularly with the reasons for optimizing utilization and reducing losses due to inefficient utilization. The target is the highest utilization of costly equipment for the productivity improvement and best possible return of the facilities.

Based on the existing problems on printing machines a proposed methodology has been suggested by conducting an in-depth analysis of variation of availability and utilization so that proper maintenance planning can be achieved.

2. Literature review

The theory behind TPM and OEE methodology started from 19th century. The idea of implementation of TPM is to increase the efficiency of a system or process or plant production by increasing the value of OEE metrics based on availability of a machine, performance efficiency of the process and rate of quality product (Nakajima, 1988). The purpose of TPM implementation is to increase the production equipment effectiveness, which is typically measured by the OEE to encourage the customers and merchants for investment and other important decisions (Mileham, et al., 1997). In this competitive production and process industry, managements are striving to improve customer's satisfaction and minimize production costs. Generally, production costs are reduced by the increment of the meantime between failures rate of the production equipment and minimizing maintenance costs of the equipment (Ramayah, Jantan and Hassan, 2002). But reduction of maintenance costs is not the solution as it may lead to ineffectiveness of the production equipment with time. If a company has an OEE of 85 % or above, then it is considered to be a world-class company. The commonly used maintenance performance indicators (Campbell and Jardine, 2001) are measured by equipment performance like availability, reliability and OEE, process performance and cost performance. Moynihan and Allwood (2014) in their journal paper stated how utilization can be used efficiently to determine the load of all structural steel beams in construction industry. Jagadeesh (2016) in his paper revealed how important is the CC for capacity planning in manufacturing industry to schedule proper job order to meet client's deadline in any deficit and surplus situation. In an another investigation it had been shown how capacity cushion (CC), utilization factor (UF) and OEE is influencing overall effectiveness of a plastic manufacturing unit where it was suggested the triple shift a day may increase productivity (Abu Jadayil, Khraisat and Shakoor, 2017). An assessment of utilization coefficient (UC) of dental equipment was conducted (Gupta, et al., 2017) at medical facility to generate maintenance schedule or timeline of hospital equipment. Generally overall equipment effectiveness (OEE) is a measure of total utilization of time, material and facilities in a manufacturing and process unit. It was further studied that OEE is a measuring system of effectiveness of a machine condition (Purba, Wijayanto and Aristiara, 2018). Nila Chandra Sakti has proposed a model of OEE along with six big losses to identify the root cause of failure and then suggested the probable maintenance method (Sakti, Nurjanah and Rimawan, 2019). Application of OEE model can be measured in the form of the real time performance indicator in manufacturing industry (Hwang, et al., 2017). The TPM can be introduced in a printing press on the basis of risk index to increase the OEE metrics and further failure probability reduction (Kar and Pal, 2019). In an another research paper it had been discussed two ways how simple moving average and Holt's double exponential smoothening methods were applied to determine OEE, to predict future performance and to minimize the error percentage (Anusha and Umasankar, 2020). An intensive study had been conducted on high downtime of continuous blanking machines and its six big losses (Marfinov and Pratama, 2020). After reviewing various journals related to OEE, it is seen that OEE is widely used by manufacturing industry (Atikno and Purba, 2021). Recently, a case study (Setiwan, Al Latif and Rimawan, 2022) was conducted to determine OEE and its performance pattern in PVC compound industry. Also a research approach is used by Azizah and Rinaldi (2022) to generate an in depth analysis to improve overall equipment effectiveness performance of a packaging company.

In the present investigation, a methodology has been developed on the basis of variation of effectiveness and utilization of printing machines for proper implementation of TPM philosophy in the press to avoid unexpected failures and downtime of these machines.

3. Theoretical background of the study

3.1 Overall equipment effectiveness and overall equipment loss measurement

The TPM technique focuses on availability (A), performance (P) and quality-rate (Q) that affect productivity. Availability losses are the result of breakdowns and change-over, i.e. the situation in which the line is experiencing unexpected stoppage. Deterioration of performance are due to speed losses and small stops or idling or empty positions i.e. the line may be running, but it is not producing the expected quantity. The above stated losses can be categorised with following Equation [1].

$$\mathrm{OEE} = \mathrm{A} \cdot \mathrm{P} \cdot \mathrm{Q} \quad [1]$$

where,

$$\mathrm{A} = \frac{\text{Operating or run time}}{\text{Total planned production time}} \quad [2]$$

$$\mathrm{P} = \frac{\dfrac{\text{Total pieces}}{\text{Operating run time}}}{\text{Ideal run rate}} \quad [3]$$

$$\mathrm{Q} = \frac{\text{Good pieces}}{\text{Total pieces}} \quad [4]$$

The quantitative assessment of OEE is central to the formulation and execution of a TPM improvement strategy. The TPM has the standard of 90 % availability, 95 % performance efficiency and 99 % rate of quality (Nakajima, 1988). Thus, an overall 85 % of OEE is considered as worldwide performance benchmark. An OEE measure provides a strong indicator for introducing a pilot and subsequently companywide TPM program. The mathematical expression of the corresponding overall equipment loss (OEL) is given in Equation [5].

$$\mathrm{OEL} = 1 - \mathrm{OEE} \quad [5]$$

The alternate way to validate the equipment losses is to estimate separately all the big losses that cause low performance of machines and equipment, namely equipment failure (breakdown losses, BL), setup and adjustment losses (SAL), idling and minor stoppage losses (IMSL), reduced speed losses (RSL), process defect losses (PDL), reduced yield losses (RYL). All six losses are summarized in Equations [6] to [11].

$$\mathrm{BL} = \frac{\text{Total breakdown or malfunction time}}{\text{Planned production time}} \quad [6]$$

$$\mathrm{SAL} = \frac{\text{Total setup, installation or adjustment time}}{\text{Planned production time}} \quad [7]$$

$$\mathrm{IMSL} = \frac{\text{Non-productive time}}{\text{Planned production time}} \quad [8]$$

$$\mathrm{RSL} = \frac{\text{Actual runtime} - \text{Ideal run time}}{\text{Planned production time}} \quad [9]$$

$$\mathrm{PDL} = \frac{\text{Ideal cycle time} \times \text{Total process defect}}{\text{Planned production time}} \quad [10]$$

$$\mathrm{RYL} = \frac{\text{Time taken for new product development or printing after rejection or damage}}{\text{Planned production time}} \quad [11]$$

3.2 Utilization factor and capacity cushion

The UF is one of the important parameters to monitor the functional status of the equipment or it is the parameter to assess the productivity of service of equipment. An optimum utilization of the equipment will result in optimal machine handling and rapid turnover with minimum possible production and maintenance cost along with client's satisfaction. The UF (also known as utilization ratio) is the ratio of actual (or present or observed) to maximum allowable performance or production time or output or value within specific limit of timeline or capacity, which is abbreviated in Equation [12] (Gupta, et al., 2017).

$$\mathrm{UF} = \frac{\text{Actual production time per day or week}}{\text{Maximum allowable production time per day or week}} \quad [12]$$

It is important to note that the actual production value or time consists of downtime, runtime, production delay, etc., for that particular shift or day or week whereas maximum allowable production time is the maximum available limit of time or performance that a system or plant can operate per shift or day or week or month.

The CC is the extra capacity available in the company that is left after utilizing the machines and equipment to produce the demanded quantity. It refers to the unused capacity and thus is maintained in anticipation of several requirements. Therefore, capacity cushion is defined as the amount of reserve capacity which a process uses to handle sudden increase in demand or temporary losses of production capacity; it measures the amount by which the average utilization (in term of total capacity) falls below 100 % as shown in Equation [13] (Jagadeesh, 2016; Abu Jadayil, Khraisat and Shakoor, 2017).

$$\mathrm{CC} = 1 - \mathrm{UF} \quad [13]$$

3.3 Failure probability and reliability

Reliability test is often carried out for both short and long span of time on a component to evaluate the failure probability, machine lifetime and its future maintenance strategies to reduce the machine breakdown and its corresponding maintenance cost. Linear regression technique is used to analyse failure pattern by the following probability Equation [14].

$$F_{x,f(x)} = \frac{p}{q} \quad [14]$$

where

$$p = [N \cdot \Sigma\{x \cdot f(x)\}] - \{\Sigma x \cdot \Sigma f(x)\} \quad [15]$$

$$q = \sqrt{[\{N \cdot \Sigma(x^2)\} - (\Sigma\, x)^2][\{N \cdot \Sigma\, f(x^2)\} - \{\Sigma\, f(x)\}^2]} \quad [16]$$

where x is breakdown time (in minutes), $f(x)$ is cumulative % of failure (calculated from number of failures per day and sum of number of failures for 91 days), N is sum of total operating time for 91 days (in minutes) and $F_{x,f(x)}$ is correlation coefficient. Failure data of the different components or sub-components of the printing press is used for determining the correlation coefficient. From the concept of probability, it is known that the value of the correlation coefficient must be between

+1.0 and −1.0. If the correlation coefficient estimates positive value, then the failure rate is increasing, otherwise the rate is decreasing. Reliability function $R(t)$ for the equipment has been calculated by using Equation [17].

$$R(t) = 1 - F(t) = 1 - \int_0^t f(t)\,dt \qquad [17]$$

The cumulative density function for reliability is denoted as $F(t)$, which is also related to failure probability and in combination with the fact that area under the probability density function is always equal to 1 (Kar and Pal, 2019). Probability density function of time to failure is denoted by $f(t)$ and t is the operating time.

3.4 Detail of printing press equipment

Maintenance is the most important duty of a printing press. The machines in an old printing house are running many years and consequently OEE, utilization, availability and reliability checking is found to be a crucial task of the printing press. In a printing press if any major machine and its supporting system has got breakdowns, the operational process would be subjected to some troubles.

The present study is conducted at Ganashakti Printer's Private Limited, a daily newspaper house, situated in Kolkata, India. This house comprises of various machines such as four colour web-offset printing machine, computer-to-plate (CTP) units and plate exposure unit, etc., in its press and prepress sections.

Computer-to-plate is an imaging device, which is used to convert an image created in desktop publishing (DTP) application into a plate made of aluminium or polyester, etc. Once the plate is imaged, it is used for four colour printing in web-offset machine. In exposure unit, printing plate is exposed by the application of ultraviolet (UV) light. The proposed observation and analysis was done on the existing four equipment, the details of which are summarized in Table 1.

Table 1: Different equipment of the daily newspaper house

No.	Machine name	Make	Year of manufacturing	Model	Approx. capacity (pieces/hr)	Output
1	Web-offset printing machine	The Printers House Pvt. Ltd, India	2009	Orient Xcell, 3c-1	41 200	Daily newspaper, supplement paper, book, magazine, etc.
2	Computer to plate 1 (CTP1)	Epson	2014	Sure Colour T5270 (Ultra Colour XD ink)	20	Preparation of plate for printing
3	Computer to plate 2 (CTP2)	Epson	2009	Sure Colour T5270 (Ultra Colour XD ink)	15	Preparation of plate for printing
4	Exposure unit	Technova	2005	Proteck, Ecolux-i	30	Preparation of plate for printing

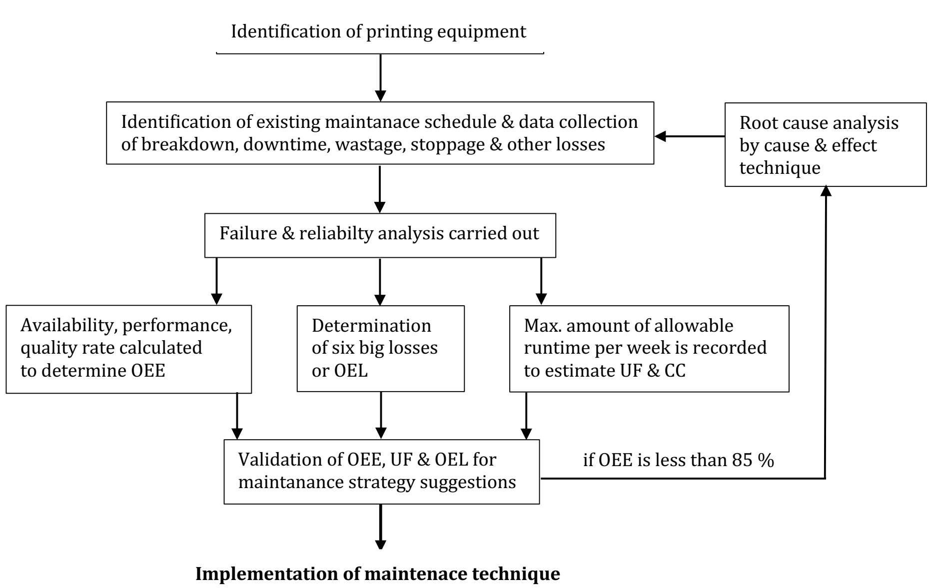


Figure 1: Framework of proposed methodology

4. Methodology

Typically, in the workflow of every print-production house, all jobs are carried out on urgent basis. Generally printing equipment works for either 12 or 24 hours a day based on the job pressure in the organization. And especially newspaper printing presses are famous for the fastest workflow process as the news of entire day needs to be covered in a predetermined and limited size of a paper roll, then that needs to undergo various approval and correction stages and then the final layout will be printed within a very short period of time as it has to be delivered to different regions and outskirts of the city. But at the same time it is very important to monitor the machine's health, production rate, breakdown, root-causes of faults and maintenance procedure in order to make appropriate performance. The present study involves the identification and documentation of all parameter leading to the estimation of overall equipment efficiency, UF and CC, failure identification and analysis of the printing machines. Apart from this, attempts have been made to examine the potential inter-relation among the parameters like OEE, OEL, six big losses and UF for each machine. Finally comparative analysis between all the factors is done on the ground of failure analysis and effectiveness of equipment to establish the suitable maintenance technique. The flowchart given in Figure 1 represents the proposed framework of the methodology.

5. Results

Basic data collected from the printing press is operating time, downtime including breakdown time, total planned production time, number of failures of the components, wastage and reworks, and total products for consecutive 13 weeks (or 91 days). The weekly collected data for web-offset printing machine and other equipment together with their ideal run rate were analysed to estimate OEE and thus OEL and are given in Appendix in Tables A1 to A4 for different machines.

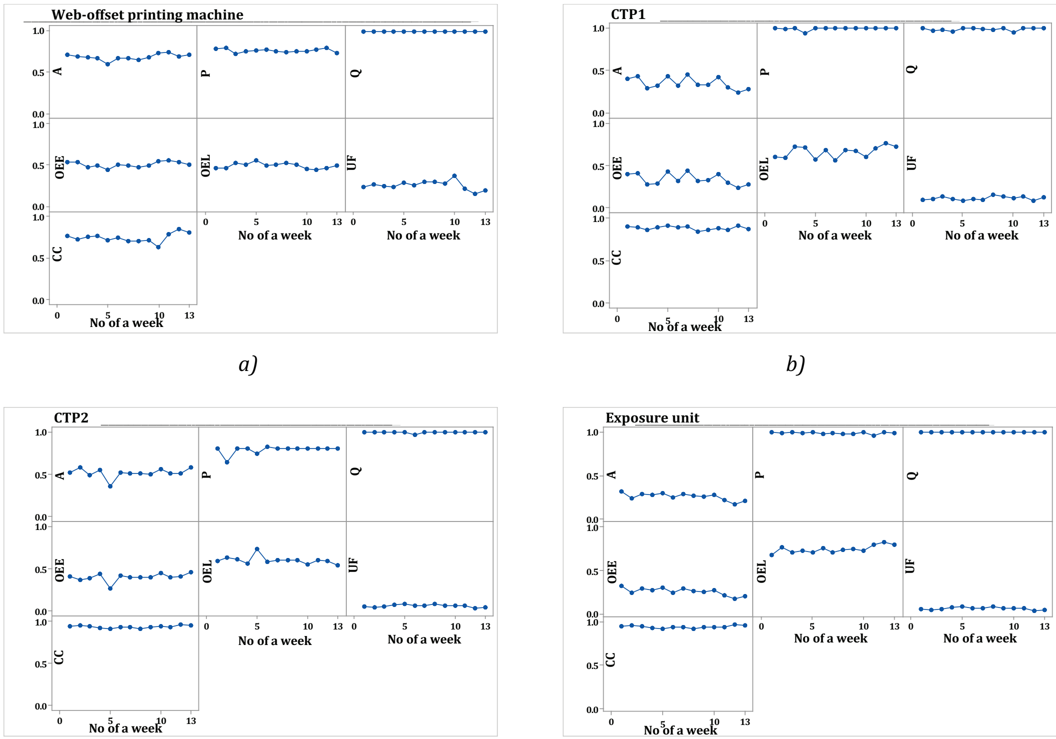
Also weekly variation and analysis of UF, and thus CC and total equipment efficency are given in Table 2 and for this maximum number of available time for each machines has been recorded. Failure time of different machines has also been noted and then compiled from the daily maintenance reports for thirteen weeks. During this investigation the average temperature inside the press was 27–33 °C and average relative air humidity was 75–85 %. Moreover, as the printing job is mostly associated with newsprint thus the press uses the paper of the same grammage and printing is done mainly in night shift though 30–35 % of the printing was done in both day and night shifts. Furthermore, it is assumed that the operational conditions are the same for all the machines.

Using Tables A1 to A4 from Appendix and Table 2, variation of A, P, Q, OEE, OEL, UF and CC for different machines in the printing house with the number of weeks are shown in Figure 2. Comparative observation of different parameters of four pieces of equipment is providing valuable insights into the actual picture of the printing house. Moreover, weekly variations of UF and CC of four pieces of equipment give a clear idea for a better understanding of the machine conditions inside the printing house.

Also, basic data of the four pieces of equipment in the printing house are represented in Table 3 for a total

Table 2: Weekly analysis of UF and CC

No. of a week	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13
Web-offset printing machine													
Max. no. of min	6 210	6 210	5 520	5 520	6 900	5 520	6 900	8 280	7 590	8 970	6 900	4 830	5 520
UF	0.2283	0.2673	0.2440	0.2303	0.2832	0.2507	0.2939	0.2943	0.2791	0.3701	0.2145	0.1482	0.1862
CC	0.7717	0.7327	0.7560	0.7697	0.7168	0.7493	0.7061	0.7057	0.7209	0.6299	0.7855	0.8518	0.8138
CTP1													
Max. no. of min	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830
UF	0.0921	0.0986	0.1340	0.1054	0.0841	0.1072	0.0961	0.1559	0.1311	0.1081	0.1313	0.0855	0.1230
CC	0.9079	0.9014	0.8660	0.8946	0.9159	0.8928	0.9039	0.8441	0.8689	0.8919	0.8687	0.9145	0.8770
CTP2													
Max. no. of min	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830
UF	0.0503	0.0451	0.0532	0.0702	0.0816	0.0598	0.0642	0.0849	0.0631	0.0578	0.0600	0.0286	0.0412
CC	0.9497	0.9549	0.9468	0.9298	0.9184	0.9402	0.9358	0.9151	0.9369	0.9422	0.9400	0.9714	0.9588
Exposure unit													
Max. no. of min	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830	4 830
UF	0.1099	0.1099	0.1222	0.1304	0.1178	0.1453	0.1427	0.1909	0.1625	0.1706	0.1857	0.1126	0.1571
CC	0.8901	0.8484	0.8778	0.8696	0.8822	0.8547	0.8573	0.8091	0.8375	0.8294	0.8143	0.8874	0.8429



a) *b)* *c)* *d)*

Figure 2: Scatterplot of availability, performance, quality, overall equipment effectiveness, overall equipment loss, utilization factor, and capacity cushion vs no. of weeks for (a) web-offset printing machine, (b) CTP1, (c) CTP2, and (d) exposure unit for 13 week

number of 91 days. From this table, Table 4 has been generated to re-estimate OEE, OEL, UF and CC values of the equipment for the total number of 91 days. Here failure probability and thus reliability of four machines have also been determined from Equations [14] and [17] to validate the results of the OEE and UF.

Table 3: Data of equipment in printing house for total 91 days

Name	Web-offset printing machine	CTP1	CTP2	Exposure unit
Operating time (minutes))	14 813	2 394	1 845	2 347
Downtime (minutes)	6 957	4 630	1 836	6 827
Total planned production time	21 770	7 024	3 671	9 174
No. of failure	506	711	284	1 146
Good pieces	7 600 443	781	362	1 157
Waste and reproduced	96 186	12	1	0
Total output	7 696 629	793	363	1 157
Ideal run rate	687	0.33	0.25	0.50

Table 4: The OEE, OEL, UF, CC, failure probability and reliability of the machines in printing house on the basis of total 91 days

Name	Web-offset printing machine	CTP1	CTP2	Exposure unit
A	0.68	0.34	0.50	0.26
P	0.76	1.00	0.79	0.98
Q	0.99	0.98	1.00	1.00
OEE	0.51	0.33	0.39	0.25
OEL	0.49	0.66	0.60	0.75
Max. no. of min	83 490	62 790	62 790	62 790
UF	0.26	0.11	0.06	0.15
CC	0.74	0.89	0.94	0.85
Failure probability	0.50	0.75	0.57	0.81
Reliability	0.50	0.25	0.43	0.19

6. Analysis and discussion

It is observed that web-offset printing machine has a high quality rate and medium rate of performance and availability, viz. 98.75 %, 75.63 % and 68.04 %, which results in a medium OEE of 50.82 %. But it is seen that only 26.07 % of available time is been utilized, which is the highest value with respect to other devices though it is the extremely low value in comparison to world class standard. To get clearest picture of effectiveness value it has to increase the utilization rate from available and unused capacity of 73.93 %. For CTP1, both performance and quality factor has a standard rate of 99.79 % and 98.49 % but OEE is affected by low availability 34.08 %. Its OEE is 33.50 % and utilization rate is 11.19 %. The corresponding CC of CTP1 thus shows that it has 88.81 % of unused capacity to utilize on the basis of 12 hour shift. CTP2 possess availability rate of 49.99 % and performance rate of 79.13 % against high quality rate of 99.72 %, resulting in low overall equipment effectiveness rate of 39.44%. Also only 5.85 % is utilized and 94.15 % of time-period remains unused. Last but not the least exposure unit has the lowest OEE value among the all four equipment, i.e. 25.22 %, and utilization rate is 14.61 %, with 85.39 % capacity unused.

For validation of the analysis of effectiveness and utilization of the four printing equipment, a comparative assessment has been done with the values of failure probability and reliability of the machines. It is observed that the exposure unit with the lowest effectiveness has the highest failure probability, whereas web-offset printing machine has the highest effectiveness with the lowest failure probability. Finally it can be said that web-offset printing machines is more reliable while exposure unit is comparatively less reliable. In general, data collection for longer duration of time would give more accurate results.

6.1 Three dimensional analysis

From the previous analysis it is observed how availability, performance, and quality are varying on weekly basis, which is directly affecting the OEE and failure probability. The quality factors of all the machines are found to be high, nearly up to the level of world standard, whereas availability and performance ratios of machines are found to be much less than the standard value. It may be due to different reasons, like prepress delay, malfunction of the machines, loading–unloading delay, material arrangement delays, sudden breakdown of machine, speed loss etc.

A 3D surface plot is useful for investigating desireable response values with the operating conditions. Operating conditions as predictors are generally on the *x* and *y* axis whereas response values are on *z* axis. So, in this case it can be postulated that availability and performance ratio are the "operating conditions" and OEE is the "response value" for the surface plot. A contour plot is also generated to visualize 3D-data in a form of 2D-plot. Figure 3 represents the surface plots and contour plots of four different pieces of equipment. From these plots, it can be seen how availability along with performance is influencing OEE of all the four machines. Here it is also observed that OEE of all the machines is far below the standard value. The values are less due to high frequency of breakdown of the machines. It is important to mention that number of failure (stoppage or downtime) of printing machine consists of loading–unloading, tear down of paper, brake problem, dampening or ink problem, change of plate due to edition, angle defect, wrong installation, inappropriate pressure in pipeline, failure in bearing and gear shaft, etc. Similarly, loading–unloading of plate in CTP machine, prepress delay, editor end-correction, machine malfunction or breakdown are the causes of downtime of CTP1 and CTP2. Loading–unloading in machine, system malfunction and breakdown, delay of exposure due to malfunction of machine or exposing bulb are the reasons of downtime for exposure unit.

It is seen that availability has relatively lower values viz. 68.04 %, 34.08 %, 49.99 %, 25.58 %, for all four machines and the quality rate has high values of 98.75 %, 98.49 %, 99.72 %, 100 %. The performance value has both medium to good values, i.e. 75.63 %, 99.79 %, 79.13 %, 98.59 %. The effectiveness parameters along with the UFs of all the machines are shown in Figure 4 in the form of a bar chart to make a comparative study of all the machines. Failure probability and reliability of the machines are also compared with the effectiveness parameters; it shows that reliability functions of all the four machines are more or less matching with the corresponding OEE values.

6.2 Analysis of six big losses

From the above discussions, it is clear that OEE of all the machines under study needs to be improved. Therefore it is necessary to determine the all six big losses which will help to identify the root causes of failures. The six big losses of all the equipment are determined by using Equations [5] to [11] and given in Table 5.

Table 5: Analysis of six big losses for all four equipment

Six big losses	Web-offset printing machine	CTP1	CTP2	Exposure unit
BL	0.0544	0.0286	0.0579	0.0235
SAL	0.2651	0.1331	0.1176	0.0581
IMSL	0.0000	0.4974	0.3233	0.6625
RSL	0.1658	0.0021	0.1068	0.0036
PDL	0.0064	0.0051	0.0054	0.0000
RYL	0.0110	0.0051	0.0014	0.0000
Total loss	0.5028	0.6716	0.6123	0.7478
OEL	0.4918	0.6650	0.6056	0.7478
OEE	0.5082	0.3350	0.3944	0.2552

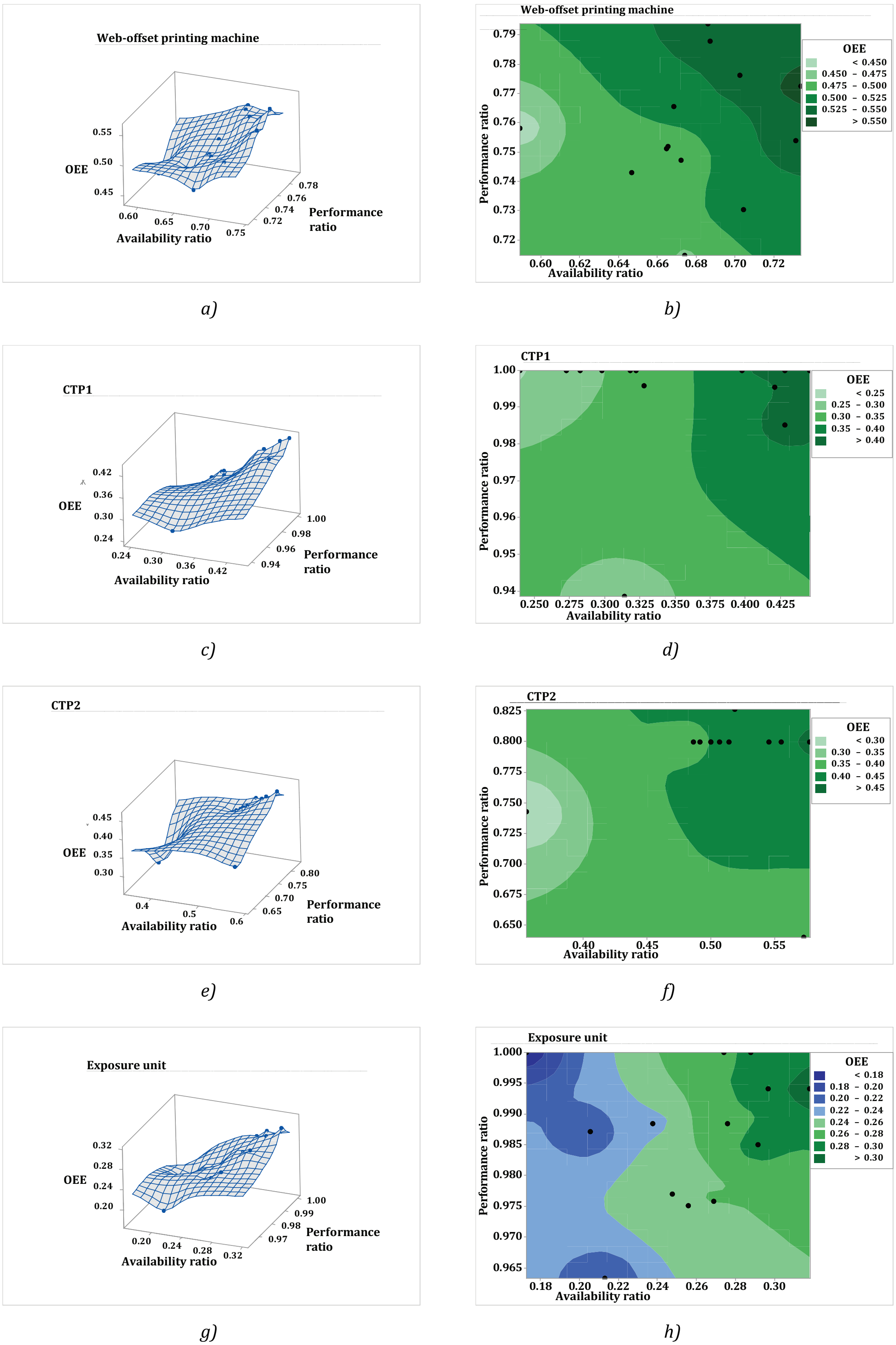


Figure 3: Surface and contour plots of overall equipment effectiveness vs performance and availability for web-offset printing machine (a) and (b), for CTP1 (c) and (d), for CTP2 (e) and (f), and for exposure unit (g) and (h), respectively

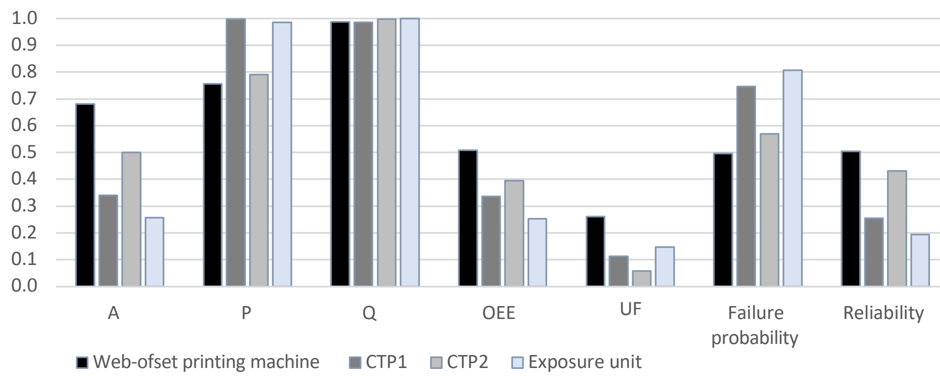


Figure 4: Comparison of effectiveness details of all four equipment

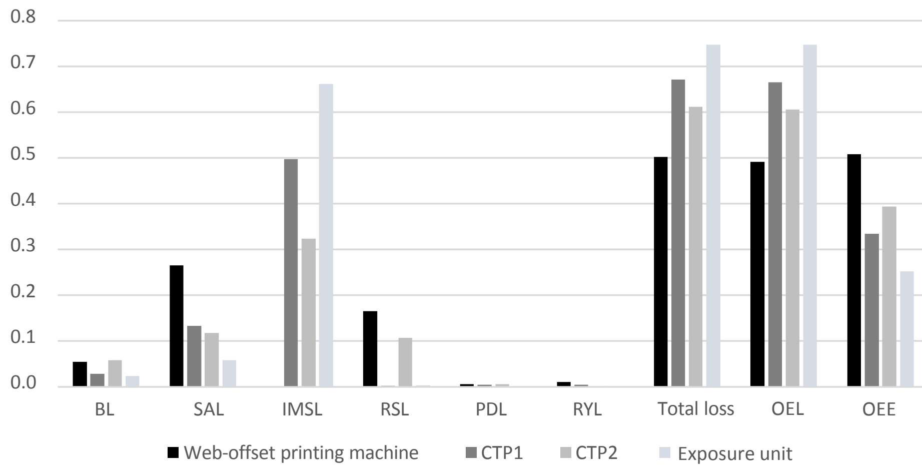


Figure 5: Comparative analysis of six big losses with OEL for four printing equipment

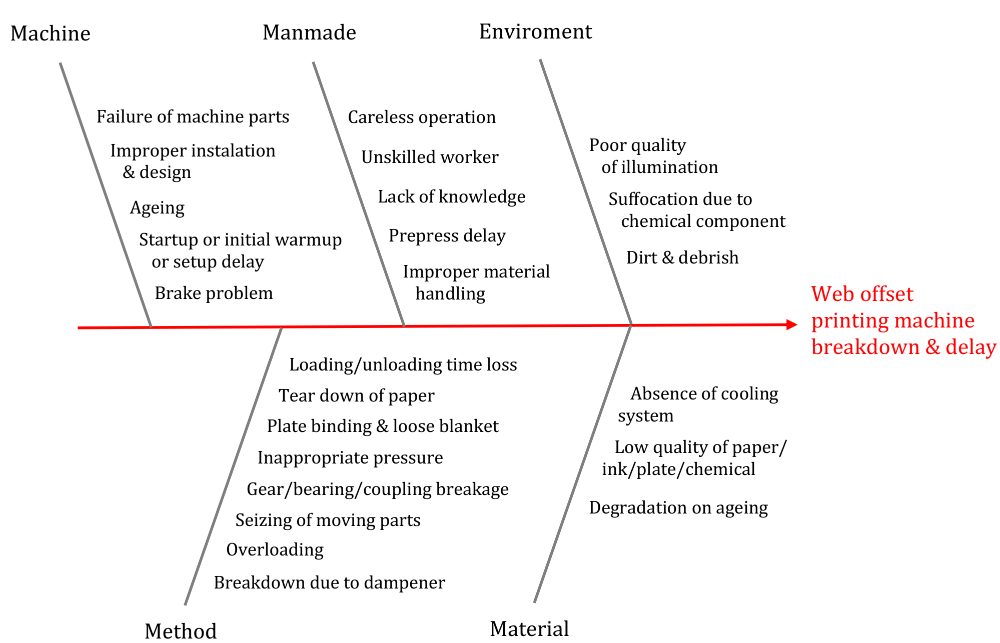


Figure 6: Fish-bone diagram (or cause and effect diagram) for web-offset printing machine breakdown

Figure 5 shows the comparative analysis of the above losses of the machines along with the OEL and OEE. Here it shows that OEL of the four machines nearly matches with the values of total losses incurred by the corresponding machines. The analysis of OEL will help to predict hidden causes of failure and probable area of improved productivity.

6.3 Ishikawa analysis

The cause and effect diagram is also known as fish-bone diagram (FBD) or Ishikawa diagram or analysis, which is composed of five main pillars namely Manmade, Machine, Method, Environment and Material. These causes lead to the main effects of failure, i.e. breakdown of a printing press. Each pillar is subdivided into different sub-branches that lead to the causes of breakdown of each component and subcomponent of the press.

Figure 6 gives the complete overview of the causes of breakdown of the web-offset printing machine. Similar diagram can also be developed for other three machines. Based on the FBD of different equipment, the causes for improper functioning and their corresponding corrective actions are listed in Table 6. The recommendations for further maintenance planning of different machines have also been suggested.

Table 7: Prediction of improved values of six big losses and OEE of the machines after implementation of TPM

Parameter Six big losses	Maximum modified parameters Web-offset printing machine	CTP1	CTP2	Exposure unit
BL	0.0000	0.0000	0.0000	0.0000
SAL	0.2804	0.2809	0.1901	0.0595
IMSL	0.0000	0.0000	0.0000	0.6785
RSL	0.1775	0.0153	0.1743	0.0037
PDL	0.0046	0.0000	0.0000	0.0000
RYL	0.0068	0.0000	0.0000	0.0000
Total loss	0.4694	0.2962	0.3644	0.7417
OEL	0.4626	0.2962	0.3643	0.7417
OEE	0.5374	0.7038	0.6356	0.2525
UF	0.2466	0.0530	0.0362	0.1427
CC	0.7534	0.9470	0.9638	0.8573

Table 6: Different types of failures of the machines and corresponding recommendations

Component / subcomponent	Causes	Corrective actions	Recommendation for maintenance approach
Web-offset printing machine	Tear down of paper, dampening and ink problem, inappropriate pressure	Continuous monitoring the given task or job to immediately detect failure	Corrective maintenance
	Brake problem	Repair	Breakdown maintenance
	Bearing, rotating element or gear shaft failure	Repair	Breakdown maintenance
	Failure due to plate and blanket	If misprint occurs due to angle of plate or disorientation of plate then replace the plate. Remake the plate again. On ageing of machine, degradation or loosening of blanket observed. Pretension of blanket or incorrect installation of blanket need proper repair.	Corrective and preventive maintenance
	Loading–unloading	Need to install automatic loading system where paper reels need to rotate with same rpm of running reel	Corrective maintenance
	Prepress delay	Detection of root cause of failure	Predictive maintenance
CTP1 and CTP2	Loading–unloading	Automation	Corrective maintenance
	Delay of printing due to malfunction machine	Detection of root cause of failure	Predictive maintenance
	Prepress delay	Detection of root cause of failure	Predictive maintenance
Exposure unit	Loading–unloading	Automation	Corrective maintenance
	Delay of exposure due to malfunction of machine or exposing bulb	Replacement or repair lighting system and detection of cause of machine malfunction	Preventive or breakdown and proactive maintenance
	Prepress delay	Detection of root cause of failure	Predictive maintenance

Based on these recommendations, modified losses, effectiveness and UF have been re-estimated by considering the fact that the downtime including breakdown time can be reduced by decreasing number of failures with the help of modern technology and management system. The modified losses values for all machines are shown in Table 7 which indicates that modified effectiveness of all the machines increases with the decrease of losses (modified) in the corresponding machines.

7. Conclusion

The OEE is a powerful tool to identify previously hidden production losses and inefficiencies. Tracking OEE scores and using them to improve in production process is a vital step towards world class manufacturing. The OEE systems provide the rich functionality necessary to expose exactly what percentage of production time is truly productive and to reveal the causes of loss productivity. Even increasing the OEE score by 1 % can lead to dramatic savings and turn-around lost production time into a positive contribution to profit. Based on the results and the analysis of OEE of different machines of a newspaper printing house it can be concluded that the measurement of effectiveness level of web-offset printing machine is comparatively high (50.82 %) but less than the world standard value of 85 %.

Web-offset printing machine is also found as the most frequently used machine owing to its UF of 26.07 %. Exposure unit is the comparatively limited used machine having lower UF of 14.61 % and downtime is more i.e. 6 827 minutes, hence OEE is less (25.22 %). The variations of OEE and utilization also give a clear picture of the printing house, where they are and where is the weakness point and how to improve.

The various problems due to different types of losses occurring in the printing press can be prevented from causing unwanted troubles leading to decrease in the overall efficiency of the system. The sequencing of jobs plays an important role to reduce the losses, wastes and time. The sequencing of jobs depends not only on operator but on the workflow also. Hence, sequencing of jobs needs to be improved for better results.

The proposed methodology influences not only maintenance management but also knowledge management because it is a quantitative method to estimate effectiveness and utilization validated by failure probability and reliability. These approaches ensure that reliability of equipment is increased after implementation of maintenance planning suggested, which may contribute to the availability of the machines as well as its safe operation. It is observed that for web-offset printing machine the percentage of increment of OEE is nearly 2.93 % after implementation of maintenance planning which is quite significant. The present investigation also helps to identify the critical equipment based on the root-cause analysis by using fish-bone diagram. Finally, it is suggested that this quantitative assessment needs to be implemented by top management in complying with the requirements of standard print production management for progressive output, effectivity, availability and productivity.

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Appendix

Weekly collected data for analysed equipment are presented in Tables A1 to A4

Table A1: The OEE and OEL measurement of web-offset printing machine

No. of a week	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13
Operating time (minutes)	996	1 139	908	846	921	925	1 348	1 576	1 424	2 428	1 086	492	724
Downtime (minutes)	422	521	439	425	642	459	680	861	694	892	394	224	304
Total planned production time (minutes)	1 418	1 660	1 347	1 271	1 563	1 384	2 028	2 437	2 118	3 320	1 480	716	1 028
No. of failure	29	38	42	32	30	29	44	61	52	93	24	13	19
Good pcs	525 437	614 045	438 000	430 938	474 151	481 039	687 410	792 991	721 027	1 239 791	571 864	263 947	359 803
Waste and reproduced	5 779	7 125	7 925	6 099	5 640	5 421	8 313	11 602	10 089	17 813	4 474	2 395	3 511
Total output	531 216	621 170	445 925	437 037	479 791	486 460	695 723	804 593	731 116	1 257 604	576 338	266 342	363 314
Ideal run rate	687	687	687	687	687	687	687	687	687	687	687	687	687
A	0.7024	0.6861	0.6741	0.6656	0.5893	0.6684	0.6647	0.6467	0.6723	0.7313	0.7338	0.6872	0.7043
P	0.7763	0.7938	0.7149	0.7520	0.7583	0.7655	0.7513	0.7431	0.7473	0.7539	0.7725	0.7880	0.7304
Q	0.9891	0.9885	0.9822	0.9860	0.9882	0.9889	0.9881	0.9856	0.9862	0.9858	0.9922	0.9910	0.9903
OEE	0.5394	0.5384	0.4733	0.4935	0.4416	0.5059	0.4934	0.4736	0.4955	0.5436	0.5624	0.5366	0.5095
OEL	0.4606	0.4616	0.5267	0.5065	0.5584	0.4941	0.5066	0.5264	0.5045	0.4564	0.4376	0.4634	0.4905

Table A2: The OEE and OEL measurement of CTP1

No. of a week	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13
Operating time (minutes)	177	204	183	153	174	165	207	247	204	220	189	99	162
Downtime (minutes)	268	272	464	356	232	353	257	506	429	302	445	314	432
Total planned production time (minutes)	445	476	647	509	406	518	464	753	633	522	634	413	594
No. of failure	56	60	61	44	51	48	61	73	61	62	58	29	47
Good pcs	59	65	60	49	58	55	68	80	68	69	63	33	54
Waste and reproduced	0	2	1	2	0	0	1	2	0	4	0	0	0
Total output	59	67	61	51	58	55	69	82	68	73	63	33	54
Ideal run rate	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333	0.3333
A	0.3978	0.4286	0.2828	0.3006	0.4286	0.3185	0.4461	0.3280	0.3223	0.4215	0.2981	0.2397	0.2727
P	1.0000	0.9853	1.0000	1.0000	1.0000	1.0000	1.0000	0.9960	1.0000	0.9955	1.0000	1.0000	1.0000
Q	1.0000	0.9701	0.9836	0.9608	1.0000	1.0000	0.9855	0.9756	1.0000	0.9452	1.0000	1.0000	1.0000
OEE	0.3978	0.4097	0.2782	0.2888	0.4286	0.3185	0.4397	0.3187	0.3223	0.3966	0.2981	0.2397	0.2727
OEL	0.6022	0.5903	0.7218	0.7112	0.5714	0.6815	0.5603	0.6813	0.6777	0.6034	0.7019	0.7603	0.7273

Table A3: The OEE and OEL measurement of CTP 2

No. of a week	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13
Operating time (minutes)	125	125	125	185	140	150	155	205	150	155	145	70	115
Downtime (minutes)	118	93	132	154	264	139	155	205	155	124	145	68	84
Total planned production time (minutes)	243	218	257	339	394	289	310	410	305	279	290	138	199
No. of failure	18	14	20	30	22	23	24	34	25	24	23	11	16
Good pcs	25	20	25	37	26	30	31	41	30	31	29	14	23
Waste and reproduced	0	0	0	0	0	1	0	0	0	0	0	0	0
Total output	25	20	25	37	26	31	31	41	30	31	29	14	23
Ideal run rate	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
A	0.5144	0.5734	0.4864	0.5457	0.3553	0.5190	0.5000	0.5000	0.4918	0.5556	0.5000	0.5072	0.5779
P	0.8000	0.6400	0.8000	0.8000	0.7429	0.8267	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
Q	1.0000	1.0000	1.0000	1.0000	1.0000	0.9677	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
OEE	0.4115	0.3670	0.3891	0.4366	0.2640	0.4152	0.4000	0.4000	0.3934	0.4444	0.4000	0.4058	0.4623
OEL	0.5885	0.6330	0.6109	0.5634	0.7360	0.5848	0.6000	0.6000	0.6066	0.5556	0.6000	0.5942	0.5377

Table A4: The OEE and OEL measurement of exposure unit

No. of a week	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13
Operating time (minutes)	169	174	170	174	169	174	201	248	201	226	191	94	156
Downtime (minutes)	362	558	420	456	400	528	488	674	584	598	706	450	603
Total planned production time (minutes)	531	732	590	630	569	702	689	922	785	824	897	544	759
No. of failure	78	84	82	83	77	78	97	120	99	125	99	52	72
Good pcs	84	86	85	86	84	85	99	121	98	113	92	47	77
Waste and reproduced	0	0	0	0	0	0	0	0	0	0	0	0	0
Total output	84	86	85	86	84	85	99	121	98	113	92	47	77
Ideal run rate	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
A	0.3183	0.2377	0.2881	0.2762	0.2970	0.2479	0.2917	0.2690	0.2561	0.2743	0.2129	0.1728	0.2055
P	0.9941	0.9885	1.0000	0.9885	0.9941	0.9770	0.9851	0.9758	0.9751	1.0000	0.9634	1.0000	0.9872
Q	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
OEE	0.3164	0.2350	0.2881	0.2730	0.2953	0.2422	0.2874	0.2625	0.2497	0.2743	0.2051	0.1728	0.2029
OEL	0.6836	0.7650	0.7119	0.7270	0.7047	0.7578	0.7126	0.7375	0.7503	0.7257	0.7949	0.8272	0.7971