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Case Study

Overall Equipment Effectiveness Analysis Using Discrete-event Simulation: A case from Table Tennis Table Manufacturer

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ABSTRACT

Make-to-order (MTO) manufacturing strategy is typically run to manage excess inventory problem which is commonly occurred in the traditional make-to-stock strategy. However, to be successfully implemented, the MTO strategy requires a proactive capacity management approach to evaluate the performance of production facilities. This lack of capability may result in difficulty to fulfill customer orders and, at the end, decrease customer satisfaction. This research proposes to analyze such issues experienced in MTO based- table tennis table manufacturing company in Indonesia striving to fulfill customer orders and arrange production schedule when demand is of a significant increase, due to occurrence of production losses. A discrete-event simulation is developed to model the production process under consideration and Overall Equipment effectiveness (OEE) method is then applied to evaluate system performance in terms of availability, performance, and quality criteria. The result revealed that the actual OEE value is lower than that of targeted value set by the company. Among those OEE criteria, the performance rate was found to lower overall OEE value since the cycle time is quite long affected by the loss in terms of machine idling, stoppage, and operating speed loss.

INTRODUCTION

The global economy has driven the expansion of competition in all business areas. By competition, it can be interpreted that the parties involved view the company through its performance. Performance appraisals may involve increased sales, increased profits, or customer growth. So that to compete in global competition, the requisition for increased performance is a necessity to meet customer expectations.

Fleischer et al. [1] state that the availability and capability of production facilities of the manufacturing companies can affect their competitiveness. The companies must be able to improve their competitiveness to survive in intense global competition [2]. This can be achieved if production losses can be minimized or even eliminated in producing products with minimum costs. This problem drives the emergence of the need for performance measurement systems that are tightly defined and able to support various important elements in the manufacturing process.

The performance evaluation of the production process motivates managers to make better decisions about how to manage and improve the production system performance effectively [3]. Companies can achieve this by determining metrics that are suitable for measurement objectives [4]. Overall Equipment Effectiveness (OEE) is a performance measurement method that is used to monitor and control the performance of production equipment [5].

Nakajima [6] proposed an OEE measurement tool developed based on the Total Productive Maintenance (TPM) concept. The goal of the TPM is to reduce equipment damage and defects to reach zero levels. The consequence of reducing damage and defects is reducing production costs, reducing inventory costs, increasing production levels, and increasing labor productivity. The TPM concept is more focused on production equipment because it has a high influence on productivity, production output, quality, cost, safety, and health.

The OEE tools can be used to identify losses that occur in the production process. Loss is a waste of resources without producing added value that can reduce the effectiveness of the equipment. Jonsson and Lesshammar [7] stated that manufacturing disorders that are chronic or sporadic can result in losses. The OEE was a bottom-up approach to improve overall equipment effectiveness by eliminating six major losses by utilizing integrated resources [6]. The six big losses can be

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categorized into three groups including downtime losses, speed losses, and quality losses.

Downtime losses are contributed by breakdown losses and set-up and adjustment losses [8]. Breakdown losses are loss of time and product quantity caused by equipment failure or damage. Set-up and adjustment losses are the setup and adjustment times required when production changes processing one item to another. Speed loss is contributed by idling and minor stoppage losses and reduced speed losses [8]. Idling and minor stoppage losses occur when the production process is interrupted by damage to the machine or idle machine. Reduced speed losses refer to the difference between the design speed of the equipment and the actual operating speed. Loss of quality is contributed by quality defects and rework and reduced yield [8]. Quality defects and rework are quality losses caused by damage to production equipment. Reduced yield during start-up is the loss of results that occur from the start of the engine until it reaches a constant condition.

The OEE is a method of measuring the productivity of equipment and machinery in a company to identify and measure loss factors from manufacturing, namely availability, performance, and quality levels [8]. It can be expressed as a comparison of the actual output of the machine divided by the maximum output of the engine while in the best condition. OEE calculations are based on three main indicators namely availability, performance rate, and quality rate. The results of OEE value calculations can provide a general view of actual performance and help focus improvements on greater losses. To get the OEE value, the three values of the three main ratios must be known first.

The availability ratio describes the utilization of time available for the operation of machines or equipment. Nakajima [6] revealed that availability is the ratio of the operation time, by eliminating equipment downtime, to loading time. Performance ratio describes the ability of equipment to produce goods against a predetermined standard speed level. Quality ratio illustrates the ability of equipment to produce products that comply with standards. The formula used for measuring the OEE as a performance indicator takes a certain period base, such as shift, daily, weekly, monthly, or yearly.

The OEE measurement is more effectively used on production equipment. It can be used in several types of levels in a corporate environment, or as a benchmark to measure a company's plans for performance. The OEE value, an estimate of production flow, can be used to compare the cross-line performance of a company, so it will be seen that the flow is not important. If the machining process is carried out individually, the OEE can identify which machines have poor performance, and even identify the focus of TPM resources.

Moreover, the OEE can measure various production losses and identify potential developments that can be carried out in a production process. According to Wireman, it is a benchmark for several processes and is part of Total Productive Maintenance (TPM) [9]. TPM is a comprehensive maintenance method developed to comply with the maintenance requirements [10]. The OEE can be used to calculate equipment efficiency because it can prevent the sub-optimization of each machine in the production line, provides a systematic approach for setting performance targets, considering process improvement initiatives, and integrate practical management tools and techniques to achieve a balanced view of process availability, performance, and quality [11].

Many studies apply OEE in measuring and improving the performance of production equipment in companies. Gupta and Vardhan [12] investigated how to increase sales volume gradually by improving the OEE of machines, plant productivity, and production cost through total productive maintenance (TPM) initiatives in a tractor manufacturing industry in India. Shahin and Isfahani [13] proposed a method for estimating OEE in continuous production lines in Esfahan Steel Company. Ranjan and Mishra [14] applied OEE to evaluate the performance of critical machines and to determine to what extent the TPM implementation can affect the OEE. The procedure for estimating OEE was also explained through a case study in the vehicle battery manufacturing industry. Fattah et al. [15] proposed an OEE improvement approach based on Best Maintenance Practices (BMPs) and implemented it in an automotive wiring mechanical machine. Sharma [16] highlighted the OEE measurement in an automobile manufacturing plant with flexible manufacturing systems by enhancing the equipment and plant reliability by eliminating all the losses incurred. Yadav et al. [17] propose a performance measurement that is derived from the OEE through modification of performance metrics. The proposed performance measurement presented an approach that combined time performance, capacity performance as well as environmental performance.

OEE is a static measurement tool that does not consider the dynamic and stochastic properties that usually occur in real conditions. The existing OEE measurement research only focuses on average data or short-term data. This does not describe metrics in real terms. To measure OEE by using overall real-time data in the long run where the data is stochastic and dynamic, it is necessary to use a discrete-event simulation (DES) model.

Discrete-event Simulation was introduced in 1961 by Geoffrey Gordon who is an IBM engineer where this method was discovered along with GPSS (General Purpose Simulation System) as the first version of discrete-event modeling. DES shows each event at a certain point of change that occurs in the system in discrete time [18]. Also, discrete occurrences are widely used in the field of operation or campaign level because they are more focused on processes within the organization such as those that occur at the payment counter at the expense center.

The event describes the system in the process flow. The process flow is the sequence of events to run the simulation. Events create delays in the simulation to replicate a time course. Events also trigger logic execution associated with events. For this type of event, it consists of a scheduled event: an event where the event can be determined and scheduled beforehand, and a conditional event that is triggered by the conditions encountered.

DES model considers both stochastic and dynamic pattern with the special discrete-event attribute that the system state variables change the value at discrete times only [19]. DES is a solution for an operating system that contains the configuration of resources combined for the supply of goods or services [20]. Robinson et al. [20] refers to it as a “business-oriented” simulation while

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interpreting business in its widest sense, for instance, the public and health sector [21]. DES model was also applied in the health care systems [22].

It is still rare to find research that uses DES to measure or analyze OEE. Mousavi and Siervo [23] presented a scalable and repeatable solution for linking the shop-floor control system to a DES model. Alzubi [24] implemented value stream mapping (VSM) and a DES model to identify sources of waste and delay in a wooden furniture manufacturing company. Barosz et al. [25] investigated the difference in work efficiency between humans and robots at the design stage. Some design variants and simulation models in FlexSim have been developed by considering the availability and reliability of the machines, operators, and robots.

The focus of this simulation model is to show the process flow of events in the system using the top-down estimation method and using the stochastic method. Also through this method, entities will determine the sequence of activities and also the period for them to wait from one situation to another [26]. Through this sequence, predictions of the next event that will occur can be seen.

DES is used by modelers to find the best solution for the emergency department to improve efficiency [27]. In discrete-event simulations, activity diagrams are used as conceptual models for evaluating interactions that occur in entities in certain events. Therefore, researchers may be able to gain more from understanding through the activity diagrams caused because they can see the sequence that links the entity and also with the resources.

Thus, in this study, the main problem discussed is the measurement of OEE value which is used as a basis for proposing improvements and increasing effectiveness, and productivity of the Finishing Division at Table Tennis Table Manufacturer. The contribution of the proposed research is providing tools to foresee the industry's future OEE score calculation. This research also has other contributions to make it easier to develop improvement scenarios and determine their impact on improving OEE values.

The production process at Table Tennis Table Manufacturer consists of the Cutting Division and the Finishing Division. The initial observation showed that the Cutting Division has a more stable condition than the Finishing Division. This can be seen from the amount of daily production that always matches the company's production target. Even for higher demand, products can exceed the target per day, while for the Finishing Division it is still difficult to meet the company's daily targets, so bottlenecks often occur between these two processes. Therefore, the improvement is focused on considering the Finishing Division by measuring the overall effectiveness of its production process.

METHOD

To evaluate the performance using OEE method, DES model was first developed for production system of Finishing Division. To applied the proposed methodology, the data were obtained from direct observation, historical company data, and interviews with relevant parties. Based on the data collected, the following assumptions are applied as follow:

1. The table tennis table consists of two main components, namely the tabletop and undercarriage. This research only investigates the tabletop component, because it is the main component that quality must be maintained in order to meet Indonesia National Standards (SNI) and International Table Tennis Federation (ITTF) standards.
2. During the 2-weeks observation between September to October 2019, only tabletops were produced.
3. The number of data is quite small implying that data normality cannot be tested. Consequently, a uniform distribution of data is assummed.
4. There exists no significant change in table specifications and machine types.

The OEE seeks to identify losses that occur in the production process associated with equipment. The OEE represents a formulation of several mutually exclusive components [2], namely: availability (A), performance (P), and quality (Q). The OEE is the result of multiplying these three factors together and can be written in (1):

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality} \quad (1)$$

Availability measures the ratio of the total time of equipment or machine that can operate (operating time) to the total machine time available (loading time). The operating time is the time of machine operates properly which isfrom a reduction from loading time with downtime (i.e. interruptions, adjustments, breakdown, and other stops). The equation (2) shows the calculation of availability :

$$\text{Availability} = \frac{\text{Operating time}}{\text{Loading time}} \quad (2)$$

where Operating time = Loading time – Downtime

Performance measures how well equipment or machine can operate in processing an item during the operational time. The performance rate is the ratio of the total cycle time required to process the total item to the operating time. The total cycle time is a multiplication of the process cycle time and the total items produced. The performance equation is presented in (3):

$$\text{Performance rate} = \frac{\text{Cycle time} \times \text{Total items}}{\text{Operating time}} \quad (3)$$

The third factor of OEE is quality. Quality is a measure of the proportion of good items (the expected specifications) with the total items produced. A good number of items is a reduction in the total number of items produced by the number of defective and rejected items. The equation for calculating quality is presented in (4):

$$\text{Quality} = \frac{\text{Total items - defects amount}}{\text{Total items}} \quad (4)$$

In this research, DES is proposed as an approach to analyze the OEE because it is suitable to enact the system that has a queue network as well as to compare and predict the scenario and focus on the process that involves the use of a queue. General procedures of developing DES are shown in Figure 1. Based on

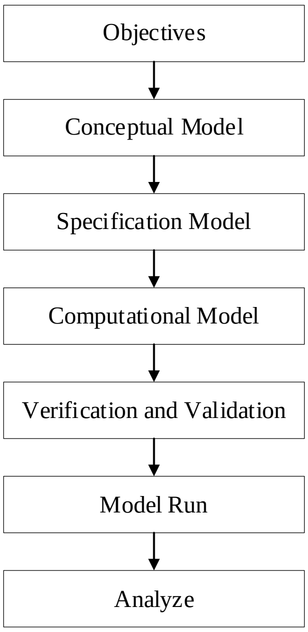

Figure 1. General Procedures of DES

the procedures, the explanation of the proposed DES production model of Finishing Division is summarized as follow.

First, the objectives are to obtain the OEE and to identify the possible losses occur in the producion process. A conceptual model is then developed based on the interviews and observation about the process flow of the Finishing Division as shown in Figure 2. After that, the conceptual model is converted to to specification model. During this process, data collection and statistical analysis were conducted to provide data input for the simulation model. If data is insufficient or unavailable, the input model must be constructed *ad hoc* using a stochastic model of which we believed to be representative. Observation was carried out during two working weeks and interview with the production supervisor of Finishing Division. Those data required to build the

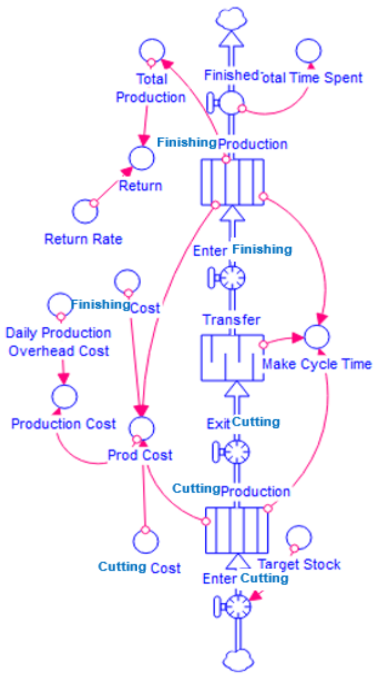

Figure 2. DES Model of The Table Production

specification model include working hours, targeted and actual cycle time, production quantities, and not-good (NG) products (defects).

The company runs 8 hours working time (Monday to Friday), and 5 hours working time for weekend (Table 1). The company set the planned downtime of 30 minutes/day. The actual downtimes are shown in Table 2. Ideally, the company has a target cycle time of 480 second/ unit produced. Using the production target of 50 unit/day (weekdays) and 32 unit /day (weekend) with thageted OEE of 80%, the standard cycle time is 455.4 second (in average). The actual cycle time was obtained from direct measurement using stopwatch during production. The result of 5 measurement/day are shown in Table 3. From this table, it can be seen that the largest average actual cycle time of 520.2 seconds occurred on September 16, 2019, and the smallest on September

Table 1. Working Time (in sec.)

No.	Date	Total Time	No	Date	Total Time
1	16-09-19	480	7	23-09-19	480
2	17-09-19	480	8	24-09-19	480
3	18-09-19	480	9	25-09-19	480
4	19-09-19	480	10	26-09-19	480
5	20-09-19	480	11	27-09-19	480
6	21-09-19	300	12	28-09-19	300

Table 2. Non-scheduled Downtime

Date	Supply (minutes)	Tools (minutes)	Total (minutes)
16-09-19	30	30	60
17-09-19	5	5	10
18-09-19	5	5	10
19-09-19	5	5	10
20-09-19	5	5	10
21-09-19	30	30	60
23-09-19	15	10	25
24-09-19	30	30	60
25-09-19	15	30	45
26-09-19	5	5	10
27-09-19	5	5	10
28-09-19	15	30	45
Total (minutes)	**165**	**190**	

Table 3. Actual Cycle Time (in sec.)

No.	Date of Measurement					
	16-09	17-09	18-09	19-09	20-09	21-09
1	518.5	527.5	517.5	511.5	515.5	502.5
2	508.0	518.5	530.5	503.0	540.5	534.0
3	515.0	510.0	512.0	506.5	503.0	520.5
4	524.0	513.0	520.5	521.5	507.5	510.5
5	535.5	504.5	508.0	503.5	521.0	550.0
Mean	520.2	514.7	517.7	509.2	517.5	523.5

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Table 4. Actual Production Data

Date	Production Unit	Date	Production Unit
16-09-19	26	23-09-19	40
17-09-19	50	24-09-19	20
18-09-19	37	25-09-19	32
19-09-19	43	26-09-19	40
20-09-19	36	27-09-19	40
21-09-19	17	28-09-19	20
Quantity		**401**	

Table 5. Defective Product

Date	NG product	Date	NG product
16-09	1	23-09	2
17-09	3	24-09	0
18-09	1	25-09	1
19-09	2	26-09	2
20-09	1	27-09	0
21-09	0	28-09	0
Quantity		**13**	

19, 2019, with a time of 509.2 seconds. Tabel 4 show the actual production rate. It shows that the largest amount of production was on September 17 with 50 unit while the smallest amount was on September 21 with a total of 17 products. The number of NG product for each day production are shown in Table 5. Based on this table, it is known that the highest number of defective products occurred on 17 September and no defective products occurred on 21, 24, 27, and 28 September. Accordingly, the total defective products during observation period were 13 products.

The specification for each dimension is thn added based on these actual data and the result is shown in Table 6. Once the specification model is completed, a computational model is developed. In this research, thesimulation model was built using STELLA Architect as a discrete-event simulation model. To ensure the computational model consistent with the specification model, a verification was carried out by adjusting the parameters and variables in the model. Validation was then performed involving the users to ensure that the model correctly represents the production of Finishing Division. Once the proposed DES model was verified and validated, the model were run using the actual data of production.

RESULT AND DISCUSSION

A simulation using STELLA Architect software is carried out and the results of performance measurement in terms of OEE value of Table Tennis Table Manufacturer are derived.

Performance Rate

Performance ratio describes the ability of equipment to produce product against a predetermined standard speed level. Based on the calculation, an average performance rate is obtained.

Table 6. Function and Mathematical Formulation

Components	Function	Formulation
Cutting Production	Cutting Division Production	Inf Cap 70 Round (Random(45; 55;0,3))
Transfer	Time for WIP transferred	Queue Round (Random(45; 55; 1))
Finishing Production	Finishing Division Production	Inf Cap 70 Round (Random(45; 55;0,3))
Total Production	Total production for each day	Round (Finishing _Production)
Return	Total defect products returned	Total Production * Return Rate
Return Rate	Return rate from defect products	0,05
Daily Prod. Overhead Cost	Daily Production Overhead Cost	5000000
Production Cost	Total Production Cost	Prod_Cost + Daily_Production_ Overhead_Cost
Prod Cost	Production Cost for both Division	Finishing Production* Finishing_Cost + Cutting_Production * Cutting_Cost)
Cutting Cost	Cost in Cutting Division per product	55000
Finishing Cost	Cost in Finishing Division per product	50000
Target Stock	Daily production target	-
Make Cycle Time	Calculate the make cycle time for one complete cycle	-
Total Time Spent	Calculate the total production time	-

Availability Rate

The availability ratio describes the utilization of time available for the operation of machines or equipment. To obtain availability rate, first the loading time and operation are determined. The result can be seen in Table 8 and

Table 7. Performance Rate

No.	Date	Actual Cycle time	Standard Cycle time	Performance rate
1	16-09-19	520.2	455.4	87.54%
2	17-09-19	514.7	455.4	88.48%
3	18-09-19	517.7	455.4	87.97%
4	19-09-19	509.2	455.4	89.43%
5	20-09-19	517.5	455.4	88.00%
6	21-09-19	523.5	455.4	86.99%
7	23-09-19	512.1	455.4	88.93%
8	24-09-19	518.6	455.4	87.81%
9	25-09-19	510.7	455.4	89.17%
10	26-09-19	519	455.4	87.75%
11	27-09-19	518.9	455.4	87.76%
12	28-09-19	530.7	455.4	85.81%

Table 8. Loading Time

No.	Date	Total time	Scheduled Downtime	Loading Time
1	16-9-19	480	30	450
2	17-9-19	480	30	450
3	18-9-19	480	30	450
4	19-9-19	480	30	450
5	20-9-19	480	30	450
6	21-9-19	300	30	270
7	23-9-19	480	30	450
8	24-9-19	480	30	450
9	25-9-19	480	30	450
10	26-9-19	480	30	450
11	27-9-19	480	30	450
12	28-9-19	300	30	270

Table 9. Operation Time

No.	Date	Loading Time	Non-Scheduled Downtime	Operation Time
1	16-9-19	450	60	390
2	17-9-19	450	10	440
3	18-9-19	450	10	440
4	19-9-19	450	10	440
5	20-9-19	450	10	440
6	21-9-19	270	60	210
7	23-9-19	450	25	425
8	24-9-19	450	60	390
9	25-9-19	450	45	405
10	26-9-19	450	10	440
11	27-9-19	450	10	440
12	28-9-19	270	45	225

Table 10. Availability Rate

No.	Date	Loading Time	Operation Time	Availability Rate
1	16-9-19	450	390	86.67%
2	17-9-19	450	440	97.78%
3	18-9-19	450	440	97.78%
4	19-9-19	450	440	97.78%
5	20-9-19	450	440	97.78%
6	21-9-19	270	210	77.78%
7	23-9-19	450	425	94.44%
8	24-9-19	450	390	86.67%
9	25-9-19	450	405	90.00%
10	26-9-19	450	440	97.78%
11	27-9-19	450	440	97.78%
12	28-9-19	270	225	83.33%

Table 11. Quality Rate

No.	Date	Total product	NG product	Good product	Quality rate
1	16-9-19	26	1	25	96.15%
2	17-9-19	50	3	47	94.00%
3	18-9-19	37	1	36	97.30%
4	19-9-19	43	2	41	95.35%
5	20-9-19	36	1	35	97.22%
6	21-9-19	17	0	17	100.00%
7	23-9-19	40	2	38	95.00%
8	24-9-19	20	0	20	100.00%
9	25-9-19	32	1	31	96.88%
10	26-9-19	40	2	38	95.00%
11	27-9-19	40	1	39	97.56%
12	28-9-19	20	0	20	100.00%

Table 9, respectively. The result of availability rate can be seen in Table 10.

Quality Rate

Quality ratio illustrates the ability of equipment to produce products that comply with standards. Similarly, the result of quality rate can be seen in Table 11.

Overall Equipment Effectiveness

Based on OEE calculations, obtained a different OEE value for each day for two weeks. From the calculation of the OEE value in the Finishing Division, the OEE value is 78.58%. Comparing with the targeted OEE of 85% from the Finishing Division it is clear that the actual OEE is below the target.

The availability rate is a ratio that describes the utilization of time available for the operation of machines or equipment. Figure 3 shows that the availability rate ranged from 77.78% to 97.78% for September 16, 2019 - September 28, 2019. The lowest availability rate value occurred on September 21, 2019, which is of 77.78%, while the highest availability rate value occurred on 17, 18, 19, 20, 26 and 27 September 2019 which are 97.78%. The average value of the availability rate is 92.13%. This value is quite good and is above the ideal availability value targeted by the company. However, if the level of downtime that occurs in the Medium Density Fiberboard (MDF) of Finishing Division can be reduced, the availability value can be further increases. Such downtime is typically non-scheduled or unplanned downtime which is caused by the time required to feed raw materials, and tools change-over.

The performance rate is calculated by comparing the actual cycle time with the ideal cycle time set by the company. Cycle times targeted by the Manufacturer is 455.4 seconds. Figure 4 presents that the value of the performance rate which is ranged from 85.81% to 89.43% (September 16 -28, 2019). The lowest value of performance rate occurred on September 28, 2019 (85.81%), while the highest value of performance rate occurred on September 19, 2019 (89.43%) with the average of 87.97%. This value is considered low for the company and this value is still below the ideal value of OEE. This lower performance is directly affected by the actual cycle time which is below the desired target

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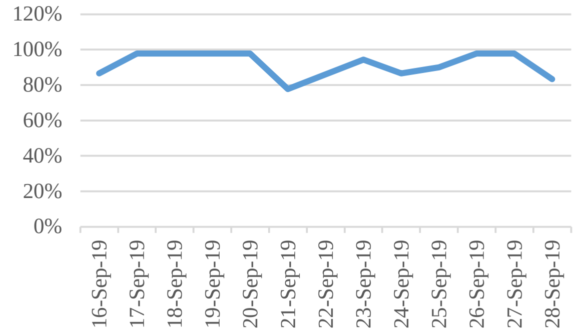

Figure 3. Availability Rate

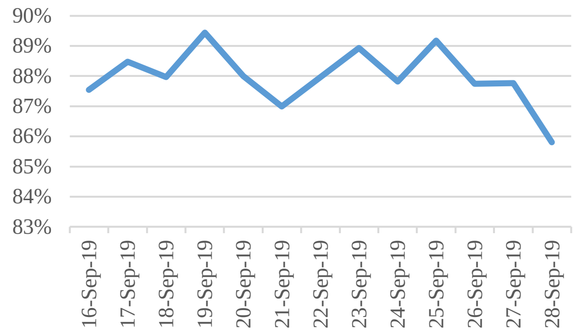

Figure 4. Performance Rate

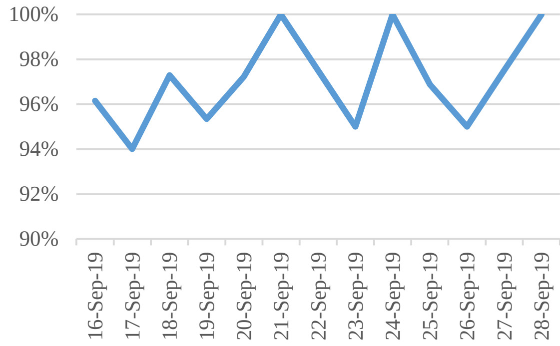

Figure 5. Quality Rate

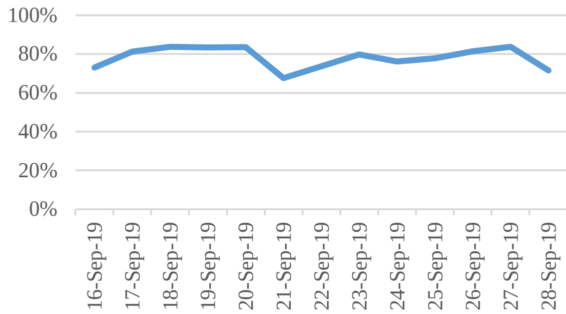

Figure 5. Overall Equipment Effectiveness

of the company due to there still many stop losses that occur during production.

Figure 5 presents that the value of quality rate ranged from 94% to 100%. The lowest quality rate value occurred on September 17, 2019, which is 94%, while the highest quality rate value occurred on September 21, 24, and September 28, 2019, which was 100%. The average value of the quality rate is 97.03% which does not meet the company's target of 99%. This is because the production batches are not too large, thus if there is a defect it will affect a fairly large percentage.

Figure 6 shows the comparison of the values of the three OEE components between average value and ideal value. These results indicate that the average value for performance and quality is still lower than the ideal value while the availability rate has met the ideal value.

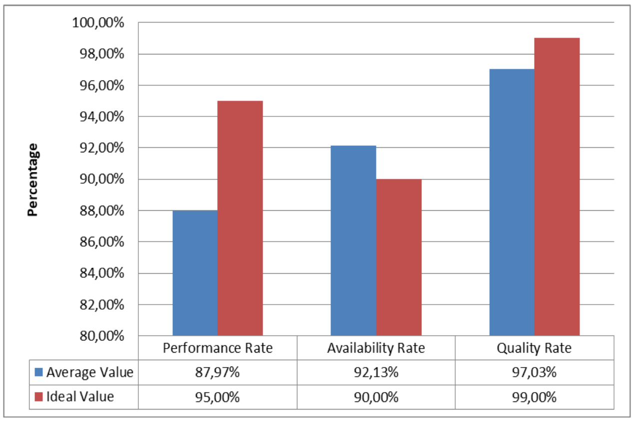

Figure 6. Comparison of Actual OEE with Ideal OEE

Overall Equipment Effectiveness (OEE) value is an indicator that shows the company's production process with a perfect production process. The average value of OEE in the Finishing Division was 78.59% which is below the ideal value of a company's OEE.

As mentioned earlier, the finishing Division of Table Tennis Table Manufacturer has set OEE targets to be achieved at 80%. The target made by the company is still below the ideal value of OEE. If seen from the OEE value obtained during the two weeks observation, there are still many OEE values that are below the target, only 6 out of 14 days the OEE value has reached 80%. Even the average OEE value is still below the company's target. The reason for the low OEE value lies in the low value of all OEE elements. Although availability rate value is already above 90%, however, it is of a great potential to be improved. In this case, the availability rate is sufficient because the stop loss that occurs is quite large. This is due to several of non-scheduled downtime, especially in the tools change-over. On the other hand, the performance rate is quite low because there is still a lot of speed loss caused by several factor such as the operator's long work and the long actual cycle time.

Recommendations for improvement are based on the analysis of the identification of the cause of the problem. After calculating using the OEE indicator, the production process in the Finishing Division has a fairly low capability. This is due to several causes, such as when viewed from the value of the performance rate due to the actual cycle time adrift far enough from the cycle time specified by the company. If seen from the availability rate, it is caused by several of non-scheduled downtime. For quality rate because there are still some NG products so that in batches that are not too large will greatly affect the percentage.

Some useful recommendation can be provided as follow:

1. Improve tools preparation and setup. This can be done by making a fast lane warehouse for tools that are disposable and frequently used, or please tool storage closer to the point of use.
2. Adjust the number of daily production batches with actual cycle times along with time tolerance so that production targets and working time are available accordingly.
3. Invest in more sophisticated machinery or quality checking machines, so they can check the state of production before sending it to the next division.

CONCLUSION

The result of this research is a discrete-event simulation model by considering the three entities in the OEE, namely availability, performance, and quality. This model can accommodate dynamic and stochastic conditions that occur in the production process. The OEE are obtained between 67.66% - 83.71% with an average of 78.59%. The value of the performance indicator has the lowest value compared to the value of availability and quality, which is equal to 87.97%. While the average value of the availability and quality indicators are 92.13% and 97.04%, respectively.

It was identified that the lower of performance rate is caused by the actual cycle time is longer than that of the company's target. In term of availability rate, the actual value is directly affected by the time taken up for non-scheduled downtime. In terms of quality rate, this value is affected by the number of NG (defective) products in large production batch. If the batch size is reduced, th amount of NG product is likely to decrease. Moreover, the company can prioritize improvements of the performance factor by reducing the occurrence of speed losses.

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