Original Research

Improved Accuracy Overall Equipment Effectiveness (OEE) Value at The Plastic Injection Process Using a Two Stage-DMAIC Fuzzy Arithmetic: A Case Studies

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Abstract

The total production capacity of a processing machine is determined using the total Equipment Effectiveness (OEE) index, which has a standard of above 71%. Managers in the industrial sector can make decisions more easily thanks to the OEE index. According to this study, a hybrid Six Sigma strategy based on fuzzy and interval arithmetic is appropriate. First, Six Sigma assesses the whole production process and provides recommendations for improvement. Second, when calculating OEE values, the two fuzzy arithmetic and interval arithmetic approaches evaluate both important and obscure aspects. As a result of the study's findings, the OEE value for the plastic injection process has increased to 88%, and the Manufacturing Execution System (MES) system has been set up to use real-time OEE monitoring with three indicators: production rate, downtime, and quality loss. This research is widely used for similar manufacturing processes making improvements from Industry 3.0 processes to Industry 4.0. The model is not new but is highly effective in analyzing production data in an uncertain environment.

Keywords - Overall Equipment Effectiveness, Fuzzy Arithmetic, DMAIC, Six Sigma, OEE

INTRODUCTION

The Overall Equipment Effectiveness (OEE) score is a crucial metric for the industrial sector that assesses the effectiveness and efficiency of equipment [1]. It evaluates the effectiveness, durability, and actual running time of the machinery. The score, which ranges from 0% to 100%, indicates the effectiveness of the device. A higher OEE score implies better equipment efficacy, whereas a lower score suggests room for improvement [2].

Six Sigma is a data-driven methodology that aims to improve business and industrial operations by reducing errors or faults. In the 1980s, Motorola invented it, and General Electric made it well-known. The sigma level of 6 is achieved through sigma initiatives that follow the DMAIC process (Define, Measure, Analyze, Improve, and Control). To ensure long-term success, project goals must be created, key metrics must be assessed, data must be analyzed, problems' underlying causes must be discovered, workable solutions must be put into place, and the process must be watched [3–4].

Utilizing industry 4.0 technology and Internet of Things (IoT) devices to digitize industrial processes and calculate OEE values is a crucial part of MES [5]. Real-time data gathering is necessary to track OEE measurements and determine production speed, downtime, and quality loss values. The impact of the production environment on the quality of the data is also influenced by the quantity of data collectors [6]. The production environment contains a variety of scenarios that interfere with data collection efforts, such as data disruptions, manually obtained data, and stopped machines or networks. It is hard to determine the OEE number with accuracy due to the quality of the data that was collected. The performance, accessibility, and quality of the material as perceived by the data collector must be considered when calculating the OEE value. By accurately calculating OEE value and keeping track of OEE value in real-time, managers may make decisions regarding the company's production and business plan more swiftly and easily [7].

The probability density function governs the calculation's accuracy because OEE value is a random variable. The analysis value of production loss values has a direct impact on how OEE is calculated, and the fuzzy coefficient calculation approach helps make production loss calculations more accurate [8]. Since the production environment is uncertain, a fuzzy index calculation approach is recommended to accurately determine the production dwell time and speed uncertainties. Production speed and downtime data are studied to determine whether production procedures are effective and to lower the risk of external interference components like human error and manufacturing defects. errors introduced by the measurement tools or the data collection procedure. The fuzzy and interval arithmetic methodologies are used to fill these gaps [9]. The MES system is designed to interface with industry 4.0 technologies to collect data in real time, reduce dependency on human skills, and minimize measurement errors [10–11]. The SQL database system's ability to link together measurement accuracy, the collection of processed parts utilizing RFID tools, and process data into a single block to help users operate more efficiently [12–14]. The following are the study's objectives: (1) Suggest using Hybrid Six Sigma, based on fuzzy math and interval math, to achieve continuous improvement. (2) Raise overall equipment effectiveness (OEE) to a level above 71%. (3) Constantly track and modify OEE metrics using the Industry 4.0 platform.

The study paper is organized in the following manner for the following sections: Section 2 presents the method and case study experience. Section 3 provides specifics on the debate, while Section 4 provides conclusions and suggestions.

METHODOLOGY AND EXPERIENCE IN CASE STUDY

DMAIC, a part of the Sigma technique, is a methodical approach to process improvement [15–16]. Five steps are defined as Define, Measure, Analyze, Improve, and Control. In the Sigma framework, the fundamental methodology known as DMAIC helps organizations identify and eliminate problems' main causes, reduce process variance, and achieve higher levels of quality and effectiveness (Table I).

TABLE I
INTERVAL AND FUZZY ARITHMETIC-BASED HYBRID SIX SIGMA TECHNIQUES

Define (D)	Measure (M)	Analysis (A)	Improve (I)	Control (C)
SIPOC Analysis	**Analyse statistical hypotheses**	Cycle time analysis	Standards Operating Procedures	**Industry 4.0 system based IoT device**
Process Patrol	Processing statistical data	Value Stream Mapping	Industry 4.0 system based IoT device	Key Performance Indicator
Man-Machine chart	Man-Machine Chart Analysis	5 Whys	**Manufacturing Execution System – MES**	Capacities Index
Video Analysis	Apply 7 QC Tools Analysis Data	**Fuzzy arithmetic and Interval arithmetic**	Fuzzy arithmetic and Interval arithmetic	Standards Operating Procedures

Define (D): The Man-Machine chart methodology can be used to show specific interactions between human and machine operations by combining the way of studying the plastic injection process with the method of video analysis. The procedure for plastic injection molding involves four steps. Process 1 oversees and provides raw resources. Semi-automatic presses are used in Process 2 to complete the molding and vulcanization of plastic products. The plastic injection product is cooled in Process 3 before being transferred to Process 4 for final inspection. If it passes, it is designated as passing and packed; otherwise, any defects are returned for additional use (Fig. 1).

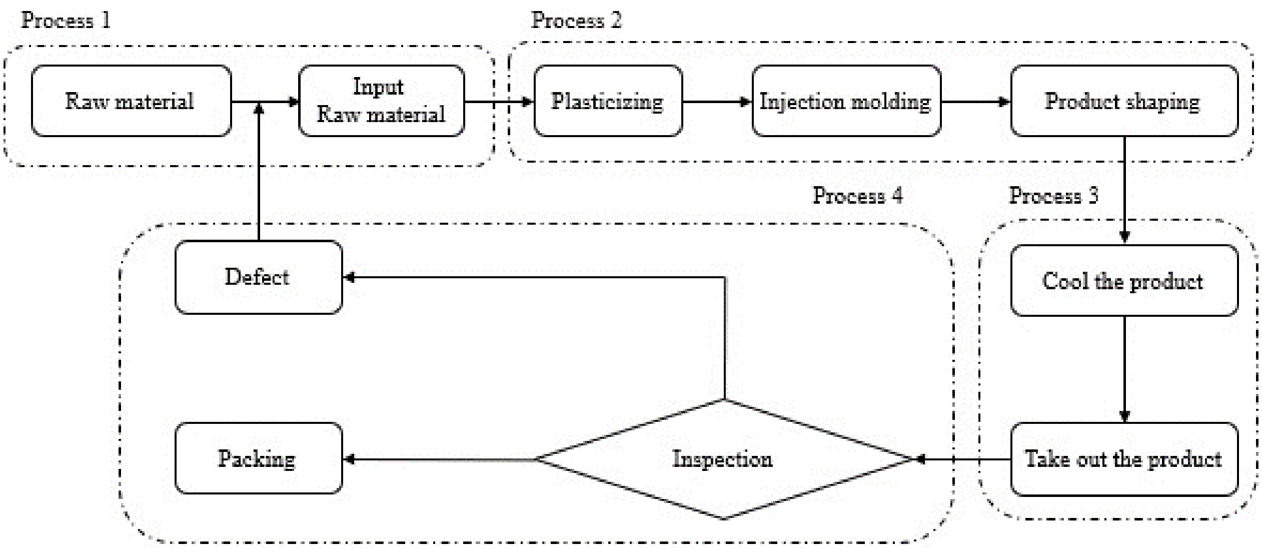

FIGURE 1
PLASTIC INJECTION PROCESS

Throughout each stage of production, a certain employee is assigned to operate the machine while standing inside it. Each phase's activities must be completed by the operator (Fig. 2). If there are people involved in the production process, there will be more downtime, higher failure rates, and longer production times.

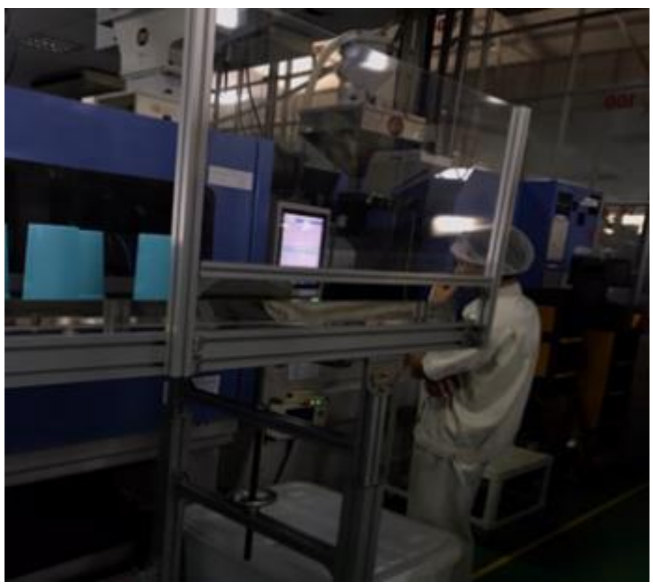

FIGURE 2
ACTUAL PLASTIC PROCESS

Measure (M) and Analysis (A): Workers from the QC department will visit the factory every two hours during the mass production process to quickly take samples at each level of production to prevent mistakes that could lead to defective products. The quality of each batch of goods will also be visually inspected by machine operators. After categorization, assuming all goes well, move on to packaging. All actions absolutely require human talents. To be able to thoroughly evaluate any flaws still affecting the factory's manufacturing process, employees manually record all the measurement data in the check sheet. The author uses the OEE (Overall Equipment Effectiveness) calculating method to further analyze how qualities like usefulness, quality, and performance affect industrial operations.

Throughout the plastic injection production process, determine the OEE value for uncertain components: The method for computing the OEE value is derived by multiplying the input characteristics for each step of production, which are availability (A) (Eq. 1), performance (P) (Eq. 2), and quality (Q) (Eq. 3). The OEE value calculation formula (Eq. 4) is calculated to minimize production-related losses. outcomes in the manufacture of plastic injections can be lost due to the tight interaction between production equipment and outcomes (Fig. 3).

$$A = \frac{T_A}{T_P} = \frac{T_P - TL_{ST}}{T_P} \quad (1)$$

$$P = \frac{CT_P}{\overline{CT_A}} = \frac{CT_P}{\left(\frac{T_A}{P_A}\right)} \quad (2)$$

$$Q = \frac{P_Q}{P_A} = \frac{P_A - PL_Q}{P_A} \quad (3)$$

$$OEE = A \times P \times Q \quad (4)$$

Where T_A: Ratio of operation time, T_P: Plan of operation time, TL_{ST}: Production stoppages losses, CT_P: Plan cycle time, $\overline{CT_A}$: Average cycle time, P_A: Numbers of product, PL_Q: Quality losses.

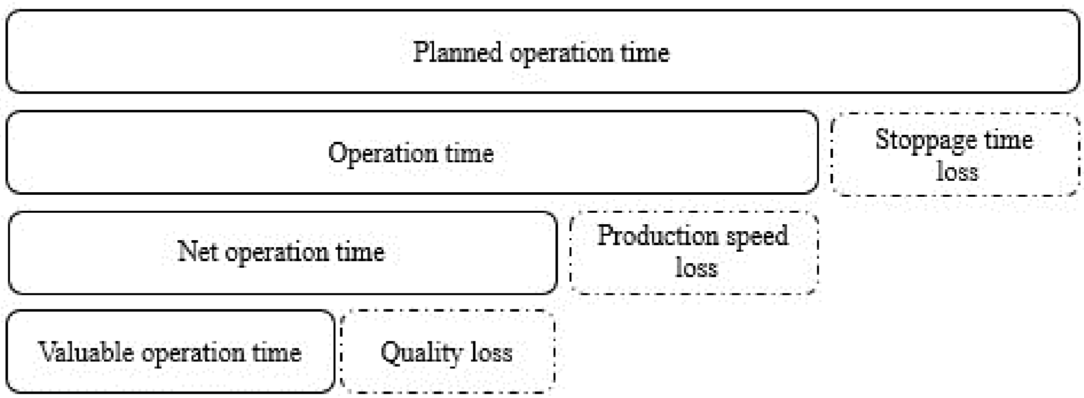

FIGURE 3
PRODUCTION AND PRODUCTION LOSS CLASSIFICATION AND RELATIONSHIPS

Producing goods requires operating machinery, and production losses are directly impacted by the accuracy of processing equipment. Employee errors include installing production tools incorrectly, calling the wrong production program for the type of product, and calling the wrong production program altogether. These errors lead to collisions during operations, deviations, and inaccurate machine alignment, which result in product loss during manufacturing (Eq. 5). Based on the study of product quality data in production using hypothesis testing statistics, quality data was obtained from the outcomes of daily check sheet checks by operations personnel, and it was discovered that 850 defective items generated losses with no obvious cause or error (Eq. 6).

$$P_P = P_Q + PL_{ST} + PL_{SP} + PL_Q \quad (5)$$

$$P_Q + PL_{ST} + PL_{SP} + PL_Q = P_A + PL_{ST} + PL_{SP} = P_A + 0 + \left(\frac{T_P}{CT_P} - \frac{T_P}{\overline{CT_A}}\right) \quad (6)$$

The targeted cycle time at the plastic injection process is 36 seconds per product, according to the production planning division. The plastic injection process has a manufacturing schedule of three shifts each day, each lasting eight hours with a 30-minute half-shift break. The suggested real manufacturing schedule is for 700 items each working day, or 25200 x 36.

Actually, 650 products are created. When compared to the production plan, it is true that it falls short of the objective set by the production planning department.

A factory that produces plastic items has its manufacturing processes affected by a range of unknown circumstances, uncertain causes, or uncertain parameters. Fishbone diagrams, correlation analysis charts, pareto diagrams, and 5 Whys analyses are a few systematic procedures that are used when the manufacturing process's performance is compromised, and the goal is not met. utilize data analysis. More samples must be used to improve sample quality, and data gathering methods must also be improved to close this gap. The key topics of this work are the analysis of production data, data on production stoppages, and data on quality losses in a production environment under erratic conditions. To find ways to replace people in production jobs, managers must investigate the noise mistake data obtained from worker actions.

Fuzzy system metrics should be used while calculating the OEE value: Stochastic mathematical models are useless in a production environment when there are many unknown parameters. Instead, fuzzy mathematical models can be quite effective in ambiguous situations. definitely. The fuzzy math model will especially be used to the process of computing OEE value for the plastic injection production process to boost the accuracy of the OEE value calculation results. In this study, the authors used fuzzy triangular numbers to determine the values of downtime, production rate, and quality losses brought on by unpredictable environments.

The fuzzy triangle math formula is used in formula (7) to determine the production halt value (($\overline{TL_{ST}}$))). There is no loss in production speed because the production speed value is determined using the production plan value figure. Equation (8) is used to construct the formula response equation for the production dwell time (($\mu_{\widetilde{TL_{ST}}}$)). Equation (9) provides a detailed description of the production cycle time averaging (($\widetilde{\widetilde{CT_A}}$), and Equation (10 describes the functions used to get the minimum value for the equipment's production cycle ($\mu_{\widetilde{\widetilde{CT_A}}}$)).

$$\widetilde{TL_{ST}} = (TL_{ST}^L, TL_{ST}^M, TL_{ST}^R) = (0, TL_{ST}, T_P - P_A CT_P) \tag{7}$$

$$\mu_{\widetilde{TL_{ST}}} = \begin{cases} 0, & x < 0 \\ \dfrac{x-0}{TL_{ST}-0}, & 0 \le x < TL_{ST} \\ \dfrac{(T_P - P_A CT_P) - x}{(T_P - P_A CT_P) - TL_{ST}}, & TL_{ST} \le x < (T_P - P_A CT_P) \\ 0, & \dfrac{T_P}{P_A} \le x \end{cases} \tag{8}$$

$$\widetilde{\widetilde{CT_A}} = (\overline{CT}_A^L, \overline{CT}_A^M, \overline{CT}_A^R) = \left(CT_P, \overline{CT_A}, \frac{T_P}{P_A}\right) \tag{9}$$

$$\mu_{\widetilde{\widetilde{CT_A}}}(x) = \begin{cases} 0, & x < CT_P \\ \dfrac{x - CT_P}{\overline{CT_A} - CT_P}, & CT_P \le x < \overline{CT_A} \\ \dfrac{\frac{T_P}{P_A} - x}{\frac{T_P}{P_A} - \overline{CT_A}}, & \overline{CT_A} \le x < \dfrac{T_P}{P_A} \\ 0, & \dfrac{T_P}{P_A} \le x \end{cases} \tag{10}$$

In a production context, quality cannot be compromised. Controlling waste loss is essential in uncertain situations. Accurately measuring quality loss not only helps managers make better business decisions, but it also improves the reliability of equipment performance metrics like OEE. Determine the likelihood of scrap's incidence and the likelihood of scrap's acceptance using formulas 11 and 12. Rework and repair are in fact counted in the amount of waste produced. then re-update the data on product quality. However, the value of rework or repairs was not considered in this research.

$$Q_1 = 2\left(1 - \int_{|x-\alpha| \le \frac{T}{2}} \varphi_x(x)dx\right) \int_0^{\frac{T}{2}} \varphi_{z_1}(z)dz \tag{11}$$

$$Q_2 = 2\left(1 - \int_{|x-\alpha|\leq\frac{T}{2}} \varphi_x(x)dx\right)\int_0^{\frac{T}{2}} \varphi_{z_2}(z)dz \quad (12)$$

Where x: Realized value, z: Measurement value, α :Standards reference value, and T: Process capability index.

To calculate the production loss value and the related production loss values, apply the fuzzy formulas (Eq. 13 and 14). The criteria necessary to measure production losses are linked and established using loss acceptance probability related to quality losses brought on by production machinery or production processes. Make use of a fuzzy method that was developed and calculated specifically to ascertain the OEE value in the production line in circumstances of coupled uncertainty. How to calculate the fuzzy availability value is shown in Equation (15). More details on how to determine the cost of fuzzy performance can be found in formula (16). Calculate the cost of fuzzy quality losses using formula (17). formula (18), which explains how to calculate the fuzzy OEE value in detail.

$$\widetilde{PL_Q} = \left(PL_Q^L, PL_Q^M, PL_Q^R\right) = \left(PL_Q - P_AQ_1, PL_Q, PL_Q + P_AQ_2\right) \quad (13)$$

$$\mu_{\widetilde{PL_Q}} = \begin{cases} 0, \quad x < PL_Q - P_AQ_1 \\ \dfrac{x - \left(PL_Q - P_AQ_1\right)}{PL_Q - \left(PL_Q - P_AQ_1\right)}, \quad PL_Q - P_AQ_1 \leq x < PL_Q \\ \dfrac{PL_Q + P_AQ_2 - x}{PL_Q - \left(PL_Q + P_AQ_2\right)}, \quad PL_Q \leq x(PL_Q + P_AQ_2 \\ 0, \quad (PL_Q + P_AQ_2 \leq x \end{cases} \quad (14)$$

$$\tilde{A} = \frac{T_P - \widetilde{TL_{ST}}}{T_P} = \left(\frac{P_ACT_P}{T_P}, \frac{T_P - TL_{ST}}{T_P}, 1\right) \quad (15)$$

$$\tilde{P} = \frac{CT_P}{\widetilde{\overline{CT_A}}} = \left(\frac{CT_P}{\frac{T_P}{P_A}}, \frac{CT_P}{\overline{\overline{CT_A}}}, 1\right) = \left(\frac{CT_PP_A}{T_P}, \frac{CT_P}{\overline{\overline{CT_A}}}, 1\right) \quad (16)$$

$$\tilde{Q} = \frac{P_A - \widetilde{PL_Q}}{P_A} = \left(\frac{P_A(1 - Q_2) - PL_Q}{P_A}, \frac{P_A - PL_Q}{P_A}, \frac{P_A(1 + Q_1) - PL_Q}{P_A}\right) \quad (17)$$

$$\widetilde{OEE} = \left(\frac{(P_ACT_P)^2\left(P_A(1 - Q_2) - PL_Q\right)}{T_P^2P_A}, \frac{(T_P - TL_{ST})CT_P(P_A - PL_Q)}{T_P\overline{CT_A}P_A}, \frac{P_A(1 + Q_1) - PL_Q}{P_A}\right) \quad (18)$$

OEE values in situations with fuzzy mixed uncertainty: measurement times: Each manufacturing process' data values are viewed as experimental contexts in a real-world production environment. The operator keeps track of information during production, which is later recorded on the check sheet. Data on production conditions such production downtime, rhythm rate, and quality loss data are collected in uncertain production situations. Data accuracy is required to increase the accuracy of the OEE value computation used in the plastic injection process. The amount of time between the beginning and end of the data gathering activity is frequently used to calculate the time. The formulas (19), (20), and (21) are used to exactly calculate these loss ranges. The estimated components that make up the OEE value are calculated using the formula that results from formulas (22), (23), and (24). The OEE value range is calculated in accordance with formula (25) and this OEE value estimate range is calculated using formula (26). This OEE value range is necessary to determine the OEE value in the confined physical environment at the plastic injection production process. The accuracy of the fuzzy method-based computation of the total OEE value in the production environment is not guaranteed by formula (27).

$$\widetilde{TL_{ST}} = \left[TL_{ST}^L, TL_{ST}^U\right] \quad (19)$$

$$\widetilde{CT_A} = \left[CT_A^L, CT_A^U\right] \quad (20)$$

$$\widetilde{PL_Q} = \left[PL_Q^L, PL_Q^U\right] \quad (21)$$

$$\tilde{A} = \left[\frac{T_A - TL_{ST}^U}{T_P}, \frac{T_A - TL_{ST}^L}{T_P}\right] \quad (22)$$

$$\tilde{P} = \left[\frac{CT_P}{CT_A^U}, \frac{CT_P}{CT_A^L}\right] \tag{23}$$

$$\tilde{Q} = \left[\frac{P_A - PL_Q^U}{P_A}, \frac{P_A - PL_Q^L}{P_A}\right] \tag{24}$$

$$\widetilde{OEE} = \left[\frac{T_A - TL_{ST}^U}{T_P}, \frac{T_A - TL_{ST}^L}{T_P}\right]\left[\frac{CT_P}{CT_A^U}, \frac{CT_P}{CT_A^L}\right]\left[\frac{P_A - PL_Q^U}{P_A}, \frac{P_A - PL_Q^L}{P_A}\right] = \frac{[T_A - TL_{ST}^U, T_A - TL_{ST}^L]\left[\frac{1}{CT_A^U}, \frac{1}{CT_A^L}\right][P_A - PL_Q^U, P_A - PL_Q^L]}{P_P P_A} \tag{25}$$

$$\widetilde{OEE} = \left[\frac{P_A CT_P}{T_P}, 1\right]\left[\frac{CT_P P_A}{T_P}, 1\right]\left[\frac{P_A(1-Q_2) - PL_Q}{P_A}, \frac{P_A(1+Q_1) - PL_Q}{P_A}\right] = \left[\frac{P_A\left(P_A(1-Q_2) - PL_Q\right)}{(P_P)^2}, \frac{P_A(1+Q_1) - PL_Q}{P_A}\right] \tag{26}$$

$$E\left(\widetilde{OEE}\right) = \frac{(1-\lambda)OEE^L + OEE^M + OEE^U}{2} \tag{27}$$

For hand-collected data sets from the factory's plastic injection production process, use a fuzzy algorithm to calculate the total OEE value based on the skills and productivity of the personnel. Figure 1 shows ABC Inc. with three operators operating on three units each at processes 2, 3, and 4, and three processing units. The first worker oversees Process 2, Process 1, and Process 2. Table II presents full results for the prior value.

IMPROVE (I) AND CONTROL (C)

Combining digital numerical control (DNC) technology with RFID and barcode technology to scan data in real time would increase data gathering accuracy and produce big data (Figure 4). In conjunction with the digital numerical control approach, sensors, internet of things (IoT) devices, and anti-interference devices are developed during the information gathering process. Using the real-time data collection technology discussed above, also known as the digital twin technique, the production environment is connected to the SQL database system and the production environment known as the improve MES. Information about machining conditions and programs is sent to the system through measurement devices and barcode scanners. Thanks to automatic program calling, automatic measurement, and real-time data transmission, there is low reliance on employee skills. Because data is collected in real-time and statistical formulas are employed to analyze it, it is simple to visualize the outcomes of data analysis over time. On the computer screen, each process is displayed in real time (Figure 5).

The use of real-time data collection technologies improves data collection accuracy under uncertain conditions. When compared to the OEE number manually recorded from the check sheet using a fuzzy method, the OEE computation produces better results.

DISSCUSION

Input factors ranging from raw materials to labor circumstances are unknown variables in the manufacturing environment for plastic goods. The quality of the manufacturing process and the accuracy of the data collection utilized to calculate the manufacturing process' OEE value are both directly impacted by all of these variables. According to the department of production engineering, certain criteria need to be ensured during production. The engineering division will alter the machine specs for the required product to increase output and decrease the percentage of defective items. By adjusting the parameters, the press will function and produce the desired quality. strength of a mold's squeeze. Ratio of raw resin to color masterbatch input, mold opening and closure (pressure velocity and location). setting the pressure on the back Temperature in the heat zones—often 5–6 heat zones—along with rotating speed, velocity, injection pressure, screw back position, holding pressure, injection time, mold temperature, if one exists, and the temperature of the cooling process for the finished product—are all factors that affect the process. The machine can begin functioning after the correct settings have been made, once it has gotten enough power and the processing heat has reached the necessary level.

The precision and timeliness of data collection directly affect the computation of OEE value, and firm managers utilize OEE value to evaluate and make decisions about production and business. Managers benefit from the precision of the OEE computation value while making choices. The accuracy of the data in the case of employee manipulation is not high since the outcomes of data collection depend on the employee's feelings and lack a foundation or yardstick for evaluation. How trustworthy is such inaccurate data or imprecise data in production have a negative impact on business strategy and decision-making.

Establish a long-term data collection system and use IOT tools like barcode scanners, RFID, and sensors to monitor the progress of production plans and collect information on the state of the production processes. Figures 7 and 8 depict how the MES system is supposed to track all OEE index-related metrics and production planning. On the screen that shows OEE-related metrics, workers and managers can see all the statistical data that the system has computed, allowing decision-makers to make decisions on production and business goals. the most risk-averse future venture. The accuracy of real-time estimated OEE numbers is a step in the right direction for future business growth.

The author has developed a MES system to handle autonomous maintenance planning and preventive maintenance. One way to increase the lifespan and uptime of the production process and decrease downtime is through maintenance activities, which have a clear plan and are carried out on schedule and in compliance with the specifications. necessary. A maintenance system utilizing Industry 4.0 technology is a crucial component that greatly improves the standard of manufacturing operations (Figure 9).

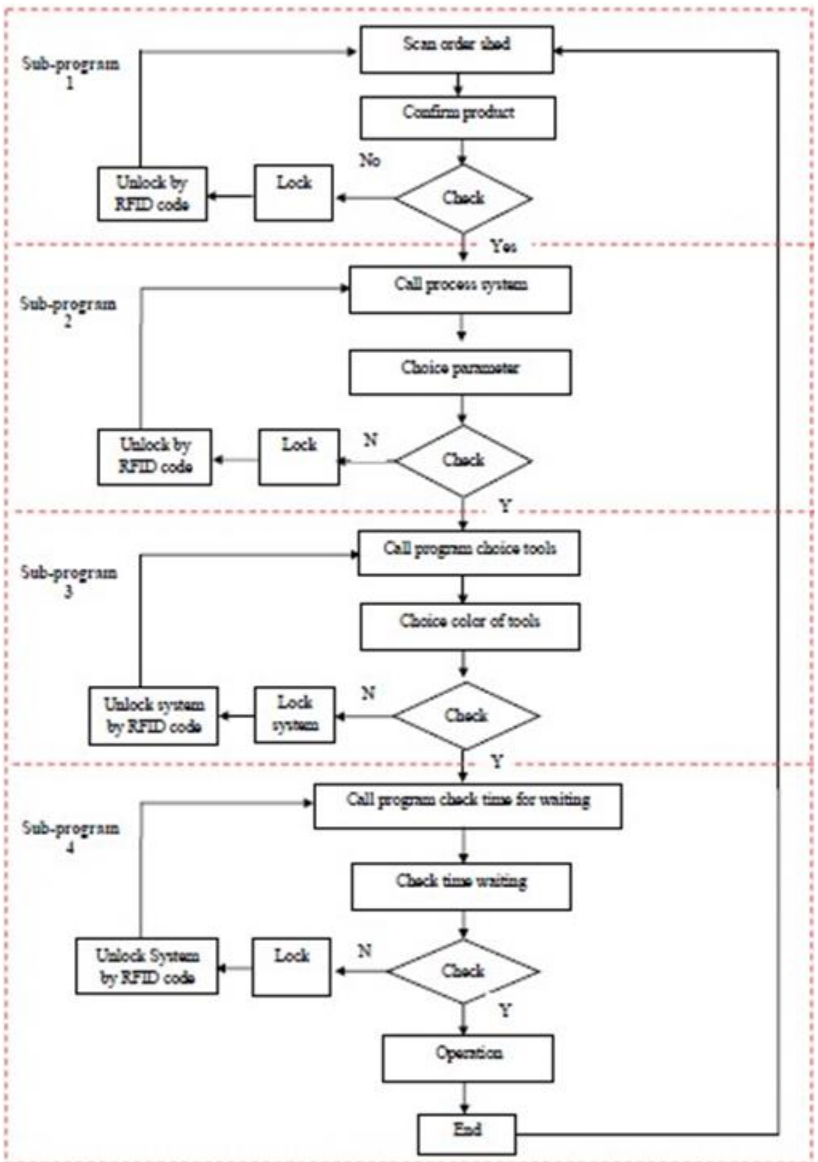

FIGURE 4
RFID SYSTEM FLOWCHART

FIGURE 5
REALTIME DATA COLLECTION

TABLE II
MEASURE OEE BEFORE AND AFTER A PRODUCTION PROCESS IMPROVEMENT

Items	Before Data collect by manual	After Data collect by RFID
	Value	
T_P	19356000s	19356000s
TL_{ST}	700s	700s
CT_P	65s	65s
$\overline{CT_A}$	75.8634s	75.8634s
P_A	25267 pcs	25267 pcs
P_Q	24872 pcs	24872 pcs
Q_1	0.018%	0.018%
Q_2	0.402%	0.402%
PL_Q	613 pcs	613 pcs
PL_{ST}	1302 pcs	1302 pcs
PL_{SP}	6 pcs	6 pcs
Actual loss	3107 pcs	4050 pcs
Calculate loss	1896 pcs	2839
Unexplained loss	1198 pcs	943
Misjudgement of inspection	489 pcs	316
Rework offline	492 pcs	627
$\widetilde{TL_{ST}}$	(0,589;189345)	(0,605;189945)
$\widetilde{CT_A}$	(76,68;887,6;83287,58)	(85,78;977,6;90287,61)
$\widetilde{PL_Q}$	(498;598;679)	(515;628;709)
$\tilde{A}$	(0,9084;0.9978;1)	(0,8984;0.8478;1)
$\tilde{P}$	(0.8906;0.9256;1)	(0.7936;0.8956;1)
$\tilde{Q}$	(0.9886;0.9885;1)	(0.8986;0.9795;1)
Conventional OEE	0.9234	0.9412
Fuzzy OEE	(0.81004;0.9234;0.98324)	(0.80004;0.9454;0.99324)
Defuzzied OEE	0.9134	0.9004
Interval OEE	(0.8562; 0.9312)	(0.7962; 0.89012)

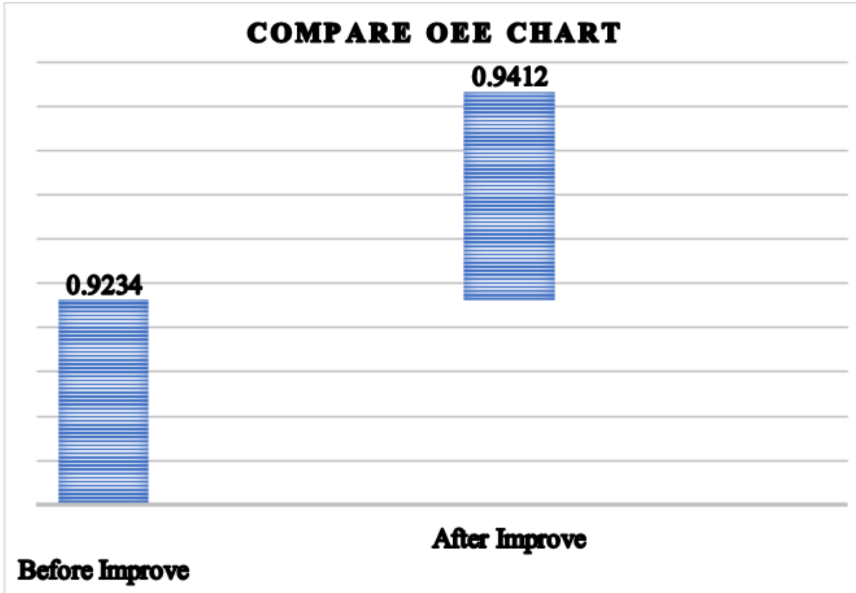

FIGURE 6
COMPARE OEE ANALYSIS.

FIGURE 7
MES SYSTEM CONTROL PRODUCTION PLAN

FIGURE 8
MES SYSTEM CONTROL OEE VALUES

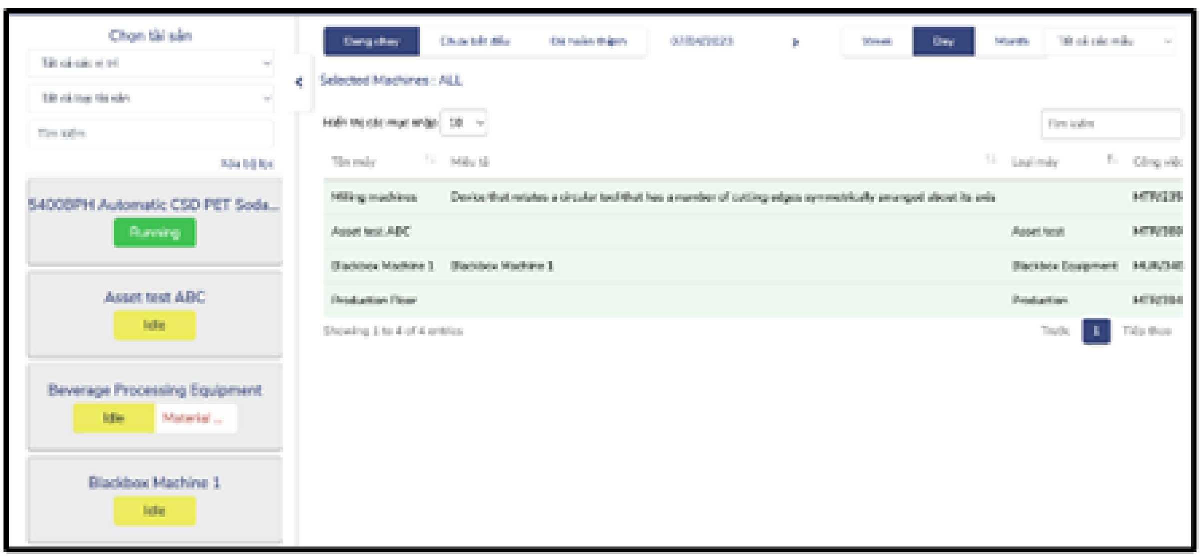

FIGURE 9
MES SYSTEM FOR MAINTENANCE ACTIVITIES

CONCLUSION

The fuzzy arithmetic and interval arithmetic approaches are used to evaluate and calculate the numbers involved in calculating the OEE value of the manufacturing process under the uncertainty situation, which increases the accuracy of data analysis. Calculate the OEE value using the data. IOT devices, fuzzy math, and interval math are used in analysis and iterative development to create a digital twin system. This system uses statistical charts to visualize real-time data collection. Data accuracy that calculates important values, such as production speed, production downtime, and quality loss, increases value accuracy OEE and assists managers in making more exact production and business decisions in unpredictable production situations.

Thanks to the MES system and the industry 4.0 system, the manufacturing process is made easier and less dependent on the actions and skills of the workers. Product quality and production conditions are automatically and continually monitored in real time. Sensor systems and barcode readers scan data through the RFID system to reduce the amount of data collected and improve data accuracy, creating a big data environment in production.

Corporate managers confront difficulties when opting to implement MES systems and industry 4.0 systems for process improvement in production since employees are not well-versed in the capabilities of IOT devices. The funding of the implementation of the industry 4.0 system presents managers with extra difficulties. However, the freedom of manufacturers inside the orgfianization to choose whether to utilize the MES system is also constrained by a difficulty with user information security and business data security while utilizing the MES system.

Businesses must concentrate on improving employee awareness within the organization and optimizing industry 4.0 system functioning in the future. Enhancing data security systems for user information and corporate data security will be the focus of future research.

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