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# Creating a digital industrial production system for control in mechatronics works

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## Abstract

This study presents the design and implementation of a production system for digital industrial applications with a focus on mechatronics control. The primary objective is to evaluate system performance using Overall Equipment Effectiveness (OEE) within a digitally integrated manufacturing environment. Operational parameters were established to maintain optimal production cycle times, and the Ideal Cycle Time (ICT) per unit was defined to ensure controllability. Experimental evaluations were conducted across multiple production cycles to quantify the principal OEE components: Availability, representing machine uptime and mitigation of unplanned downtime; Performance, reflecting production rate relative to predefined standards; and Quality, indicating product conformance and defect rates. The results demonstrate that the production system attains high overall effectiveness, exhibiting consistent availability, production speed, and product quality in alignment with industrial benchmarks. Notably, the system shows robustness in maintaining stable cycle times and product quality across most production rounds. Nevertheless, certain cycles experienced reduced availability due to elevated downtime, directly affecting overall OEE. The findings suggest that implementing strategies to minimize unplanned downtime and optimize planned maintenance can further enhance system performance, promoting sustained operational efficiency and reliability in advanced manufacturing settings.

**Keywords:** Digital industry, IoT, Mechatronic work, Production system.

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## 1. Introduction

In the current era, industries worldwide are experiencing rapid transformations under the paradigm of Industry 4.0, which emphasizes the integration of digital technologies, automation, and Artificial Intelligence (AI) into manufacturing processes to enhance efficiency, flexibility, and competitiveness. A key aspect of this transition is the development of production systems capable of real-time data integration, control, and decision-making, consistent with the principles of Digital Manufacturing [1-3].

The field of Mechatronics represents an interdisciplinary domain that combines mechanical engineering, electrical engineering, electronics, control systems, and software engineering to develop automated and intelligent systems with high precision and efficiency. In industrial applications, mechatronic systems require expertise in both hardware components, such as sensors, actuators, and programmable logic controllers (PLCs), and control software capable of rapid data communication and analysis from the shop floor [4-7].

However, practical manufacturing environments often face challenges including unplanned downtime, variable production efficiency due to fluctuations in cycle time, product quality issues leading to defects, and delayed decision-making due to insufficient real-time monitoring. These problems not only adversely affect Overall Equipment Effectiveness (OEE) but also reduce the long-term competitiveness of organizations [8-10].

Therefore, there is a critical need to develop production systems for digital industry applications in mechatronics, which can automatically measure and record production data, including operating time, planned breaks, unplanned downtime, production output, and the number of conforming products. The system calculates key performance indicators (KPIs) such as Availability, Performance, Quality, and OEE to analyze issues and improve production processes [11-13]. Integration with digital control systems enables automated responses and alerts when performance falls below predefined standards, while predictive analytics can anticipate and prevent potential problems.

This research is thus significant for advancing manufacturing processes to meet modern industrial standards, not only by improving efficiency and reducing costs but also by creating knowledge and prototypes for mechatronic systems that can be practically applied in industrial settings. Additionally, it provides an educational tool for engineering students, preparing them for the digital industrial workforce.

## 2. Methodology

The research project on developing a production system for Digital Manufacturing applications in Mechatronics was implemented using a two-part automated production simulation setup. In Part 1, the system was controlled by a single Programmable Logic Controller (PLC). The production process began at Conveyor 1 and continued to Conveyor 2, where two types of workpieces metal and non-metal were sorted. The process concluded at the final stage with a vacuum system that picked up the sorted workpieces and placed them into designated boxes.

In Part 2, the system was enhanced to include an advanced workpiece conveying process, controlled by PLC 1 and PLC 2. This stage enabled sorting of three types of workpieces: metal, shiny non-metal, and matte black non-metal. Incoming workpieces were counted, and the sorted quantities were displayed on a Human-Machine Interface (HMI) touchscreen. Additionally, the system supported remote operation and monitoring of the PLCs via an IoT-based network connected through the Internet.

### *2.1. Design and Construction of a Production System for Digital Manufacturing Control in Mechatronics*

A production system was designed and constructed for digital manufacturing applications in mechatronics control, comprising the following components in the simulated production line, as shown in Figure 2.

1. Conveyor System 1 for transporting workpieces along the initial stage of the production line.
2. Lift and Pusher Mechanism simulating a lift to raise workpieces and pneumatic cylinders to push them onto the sliding rails.
3. Conveyor System 2 with Metallic Workpiece Sorting for transporting and separating metallic workpieces.
4. Sliding and Vacuum Cylinder Unit incorporating sliding pneumatic cylinders and vacuum cylinders for picking and placing workpieces.
5. Conveyor System 3 with Yellow Shiny Non-Metallic Workpiece Sorting for transporting and sorting non-metallic workpieces with a glossy yellow surface.
6. Ball Screw Sliding Unit with Stepping Motor and Gripper for precise workpiece transfer using a stepper motor-driven ball screw and robotic gripper.
7. Conveyor System 4 with Matte Non-Metallic Workpiece Sorting for transporting and separating non-metallic workpieces with a matte surface.

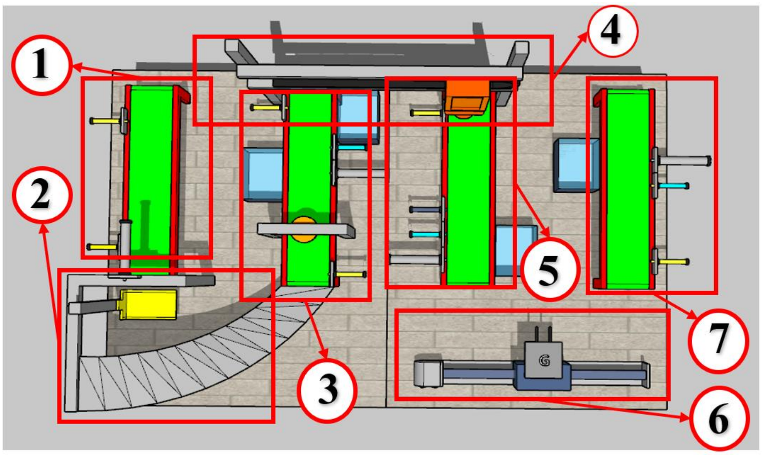


**Figure 1.**
Design of digital industrial production systems for mechatronics control

*2.2. Design of the Pneumatic Circuit*

The power circuit of the pneumatic system was designed using a specialized design software to illustrate the operation of cylinders and manual valves for controlling the actuators, as well as to indicate the types of sensors employed in the system. In this simulation setup, 5/2 and 3/2 solenoid valves are primarily used. The system incorporates electrically actuated valves with pneumatic return and spring mechanisms. Additionally, flow control valves are installed to regulate the cylinder speed, preventing potential damage. The pneumatic control circuit for the first part of the simulated production process is detailed in Figures 3 and 4, which depict the control circuit of the newly developed production process simulation.

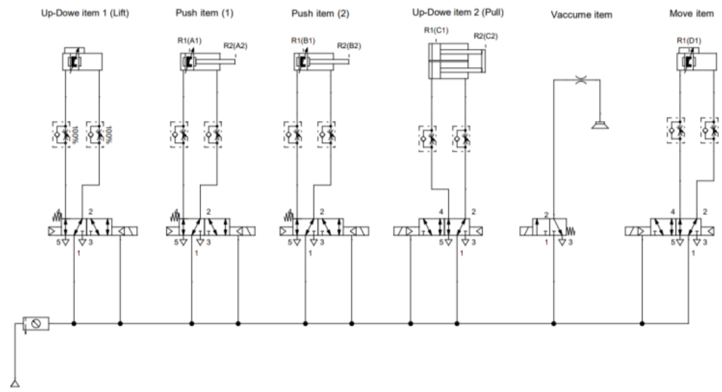


**Figure 2.**
The pneumatic control circuit for the first part of the simulated production process.

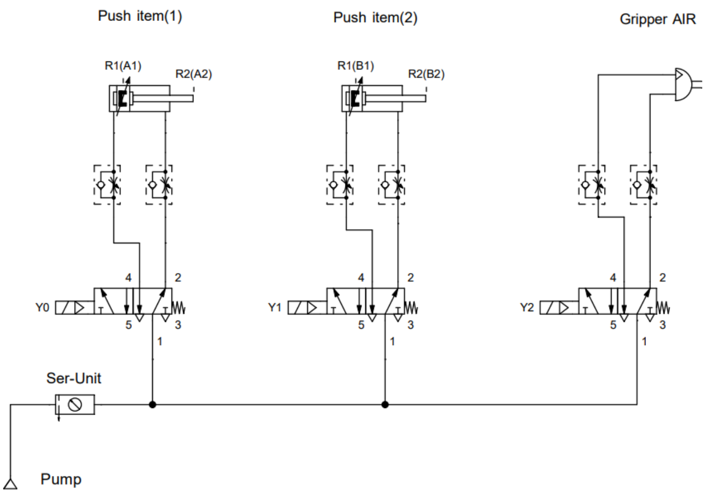


**Figure 3.**
The control circuit of the newly developed production process simulation

### *2.3. Design of the Input and Output Wiring Diagram*

In this study, two PLC units were employed as the primary devices for programming control. Process monitoring and command execution were conducted via a touch screen interface and an IoT system. The selected PLCs are Mitsubishi FX5U models, with each unit providing a total of 32 I/O points. The input types include both sink and source configurations, with 12 input points utilized and 11 output points utilized. The input and output wiring circuit for Production Process Set 1 is shown in Figure 4. Input and output wiring circuit for Production Process Set 2, as shown in Figure 5.

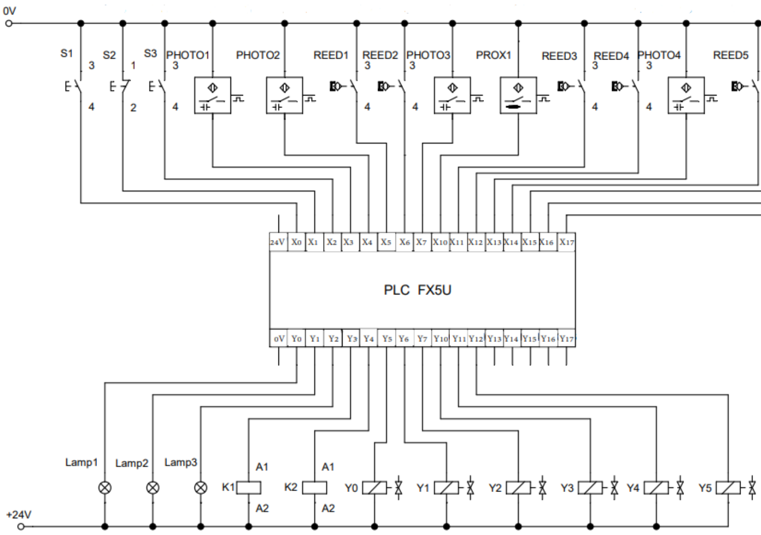


**Figure 4.**
Input and output wiring circuit for Production Process Set 1.

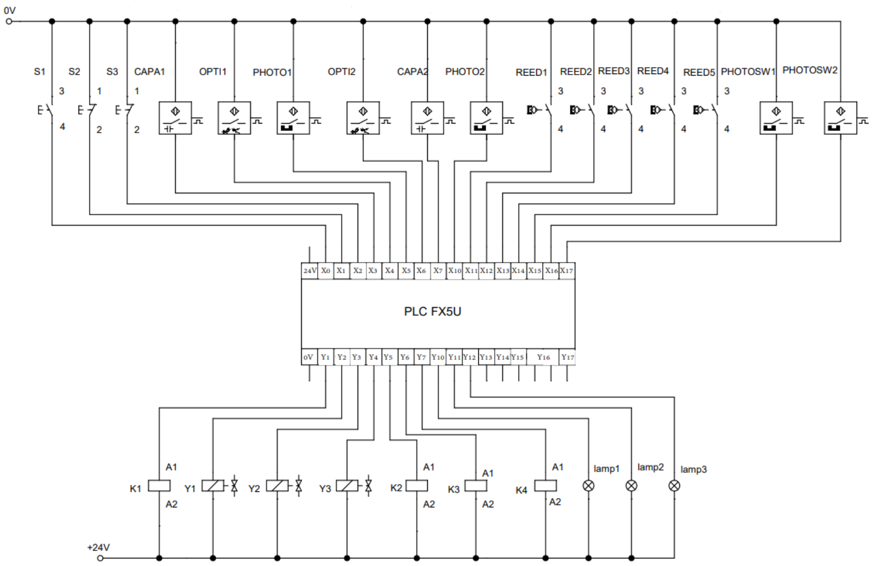


**Figure 5.**
Input and output wiring circuit for Production Process Set 2.

### *2.4. Design And Integration of Equipment for the Production Process Simulation Setup*

The design and installation of the control circuit for the simulation setup were carried out with careful consideration of the current and voltage ratings to ensure compatibility with the equipment. Power supply capacity was selected to adequately feed all devices without exceeding limits that could cause overload or falling short, which would result in insufficient voltage. Cable trays were chosen based on the type of work and the amount of wiring required for connections between devices. Finally, all equipment was connected to the control panel, enabling integration with the PLC used for system control, as shown in Figures 6 and 7.

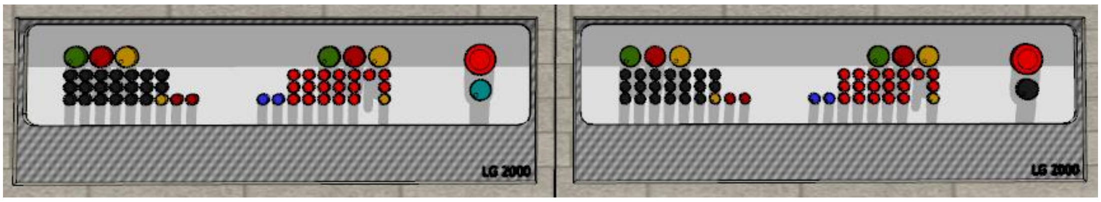


**Figure 6.**
Design of the front panel of the control unit.

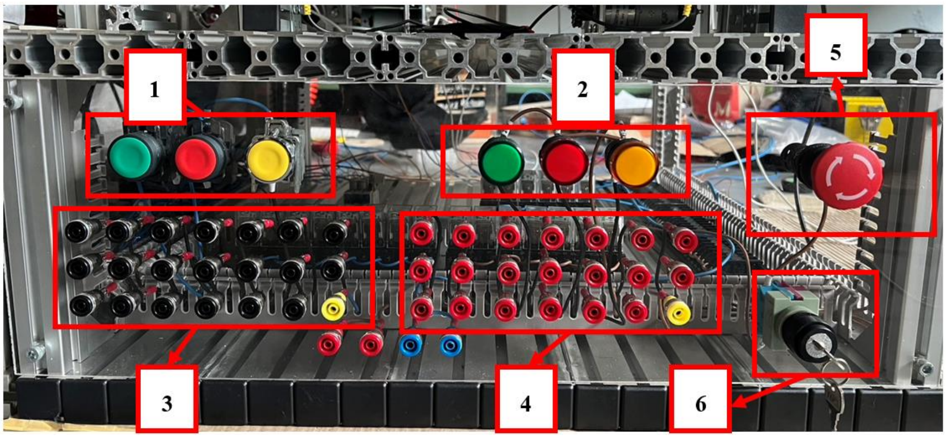


**Figure 7.**
Front view of the completed control panel.

In Figure 7, the front panel of the control unit is designed with the following components:
1.Push Button Switches: Three buttons, including Start, Stop, and Reset switches.
2.Indicator Lamps: Three status lamps corresponding to Start, Stop, and Reset functions.
3.Input Wiring Terminals: Black-colored terminals on the left for connecting PLC input signals.
4.Output Wiring Terminals: Red-colored terminals on the right for connecting PLC output signals.
5.Emergency Switch: For use in emergency situations, along with a 24 V connection point.
6.On/Off Switch: Controls 220 V AC and 24 V DC at 20 A, serving as the main power supply for the entire circuit.

*2.5. Measurement of the Overall Effectiveness of the Production Simulation Setup*

Measurement of the Overall Effectiveness of the Production Simulation Setup (Overall Equipment Effectiveness, OEE) is a method used to assess machine efficiency and identify the causes of losses occurring within the system. It allows the separation of losses and their underlying causes, enabling accurate improvements and reduction of inefficiencies. Therefore, this study applies OEE analysis to evaluate the operational effectiveness of the automated production simulation setup. The details are described by the following equations:

*2.5.1. Availability*

Availability represents the operational readiness of the machine. Examples of factors reducing availability include unplanned downtime, machine failures, installation errors, and operational mistakes. It is calculated by Equation 1 [14-16].

$$\text{Availability} = \frac{\text{Operating time}}{\text{Load time}} \text{ x } 100 \quad (1)$$

Where:
Availability is the machine uptime percentage
Operating time is machine running time (load time minus downtime)
Load time is the total scheduled time (total working time minus planned breaks)

*2.5.2. Performance Efficiency*

Performance Efficiency evaluates machine output relative to its production capacity. It indicates whether the machine is operating at full potential. It can be calculated using Equation 2 [13-15].

$$\text{Performance Efficiency} = \frac{\text{Ideal cycle time x Processed amount}}{\text{Operation time}} \text{ x } 100 \quad (2)$$

Where:

Performance Efficiency is the operational efficiency of the machine
Ideal cycle time is the standard time per unit
Processed amount is the number of units produced
Operating time is the machine running time

*2.5.3. Quality Rate*

Quality Rate measures production quality by comparing the number of acceptable units to total output. It reflects the ability to produce defect-free products witch calculated using Equation 3 [13-15].

$$\text{Quality rate} = \frac{(\text{Actual output} - \text{Defects})}{\text{Actual output}} \times 100 \quad (3)$$

Where:
Quality Rate is the product quality percentage
Actual output is the total units produced
Defects is the number of defective units

*2.5.4. Overall Equipment Effectiveness (OEE)*

OEE combines Availability, Performance Efficiency, and Quality Rate to provide an overall measure of production effectiveness. It can be calculated using Equation 4 [13-15].

$$\text{OEE} = \text{Availability} \times \text{Performance efficiency} \times \text{Quality rate} \quad (4)$$

Where:
OEE is the overall effectiveness of the production simulation setup
Availability is the machine uptime percentage
Performance Efficiency is operational efficiency
Quality Rate is the product quality percentage

This methodology enables systematic evaluation and improvement of machine performance, minimizing losses and enhancing production efficiency.

## 3. Results and Discussion

The experimental results include recorded values of operating time, scheduled breaks, unplanned downtime, total pieces produced, and the number of good pieces for the production system used in digital industrial control for mechatronics applications. The production was conducted within a working period not exceeding 1 hour, with a standard production time (Ideal Cycle Time, ICT) of no more than 1 minute per piece, over 20 production cycles, as shown in Figure 8.

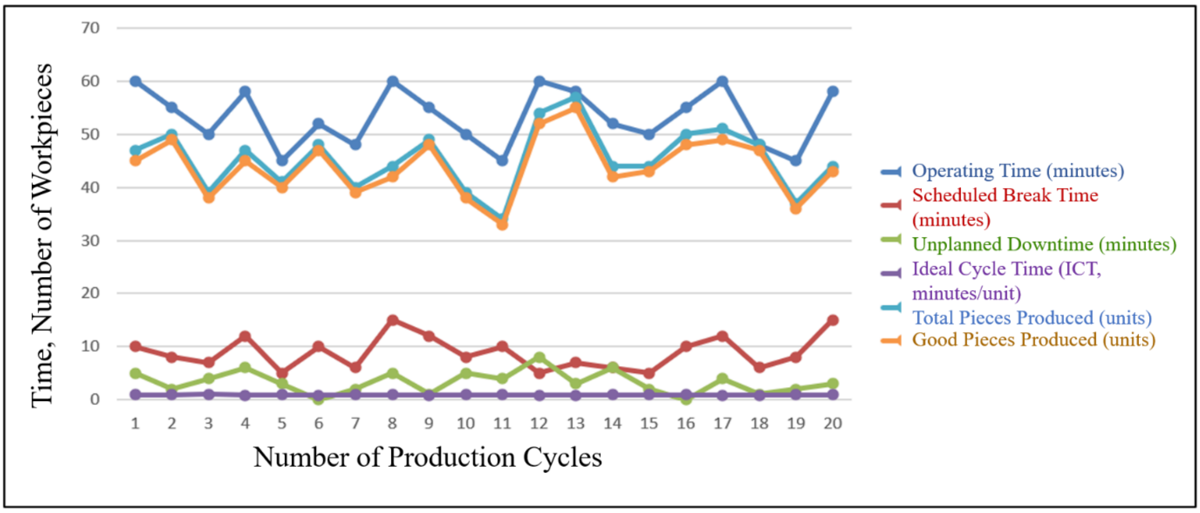


**Figure 8.**
Experimental data of the production system for digital industrial applications in mechatronics control.

From the experimental data over 20 production cycles, each cycle was performed under different conditions and working times to collect comparative information on production efficiency. The working time of each cycle ranged between 45-60 minutes, with the longest cycles lasting 60 minutes (Cycles 1, 8, 12, and 17), and the shortest cycles lasting 45 minutes (Cycles 5, 11, and 19). The scheduled break time was set between 5-15 minutes, with the shortest break of 5 minutes observed in Cycles 5, 12, and 15, and the longest break of 15 minutes in Cycles 8 and 20, which directly affected the Planned Production Time. Unplanned downtime during the experiment ranged from 0–8 minutes. Cycles 6 and 16 experienced no downtime, which provided an opportunity for higher Availability. In contrast, Cycle 12 had the maximum downtime of 8 minutes, potentially impacting production output. The Ideal Cycle Time (ICT) ranged from 0.85–1.00 minutes per piece. The lowest ICT of 0.85 minutes per piece occurred in Cycles 4, 9, 13, and 18, reflecting faster production capability, while the highest ICT of 1.00 minute per piece occurred in Cycle 3, representing the standard production rate.

The number of pieces produced per cycle ranged from 34–57 pieces. The highest production output was in Cycle 13, with 57 pieces, while the lowest was in Cycle 11, with 34 pieces. This variation depended on both Run Time and ICT. The number of good pieces remained high across all cycles, ranging from 33–55 pieces. Cycle 13 recorded the highest number of good pieces (55 pieces), while Cycle 11 recorded the lowest (33 pieces). These differences were influenced by both production rate and defect rate in each cycle. Based on the data presented in Figure 8, the Availability values can be calculated using Equation 1, as illustrated in Table 1.

**Table 1.**
Calculation of Availability.

| Work Cycle | Working Time (min) | Planned Break Time (min) | Unplanned Downtime (min) | Planned Production Time (min) | Runtime (min) | Availability (%) |
|---|---|---|---|---|---|---|
| 1 | 60 | 10 | 5 | 50 | 45 | 90.00 |
| 2 | 55 | 8 | 2 | 47 | 45 | 95.74 |
| 3 | 50 | 7 | 4 | 43 | 39 | 90.70 |
| 4 | 58 | 12 | 6 | 46 | 40 | 86.96 |
| 5 | 45 | 5 | 3 | 40 | 37 | 92.50 |
| 6 | 52 | 10 | 0 | 42 | 42 | 100.00 |
| 7 | 48 | 6 | 2 | 42 | 40 | 95.24 |
| 8 | 60 | 15 | 5 | 45 | 40 | 88.89 |
| 9 | 55 | 12 | 1 | 43 | 42 | 97.67 |
| 10 | 50 | 8 | 5 | 42 | 37 | 88.10 |
| 11 | 45 | 10 | 4 | 35 | 31 | 88.57 |
| 12 | 60 | 5 | 8 | 55 | 47 | 85.45 |
| 13 | 58 | 7 | 3 | 51 | 48 | 94.12 |
| 14 | 52 | 6 | 6 | 46 | 40 | 86.96 |
| 15 | 50 | 5 | 2 | 45 | 43 | 95.56 |
| 16 | 55 | 10 | 0 | 45 | 45 | 100.00 |
| 17 | 60 | 12 | 4 | 48 | 44 | 91.67 |
| 18 | 48 | 6 | 1 | 42 | 41 | 97.62 |
| 19 | 45 | 8 | 2 | 37 | 35 | 94.59 |
| 20 | 58 | 15 | 3 | 43 | 40 | 93.02 |

From Table 1, the comparison graph of Planned Production Time, Run Time, and Availability, calculated from the experimental data, is shown in Figure 9.

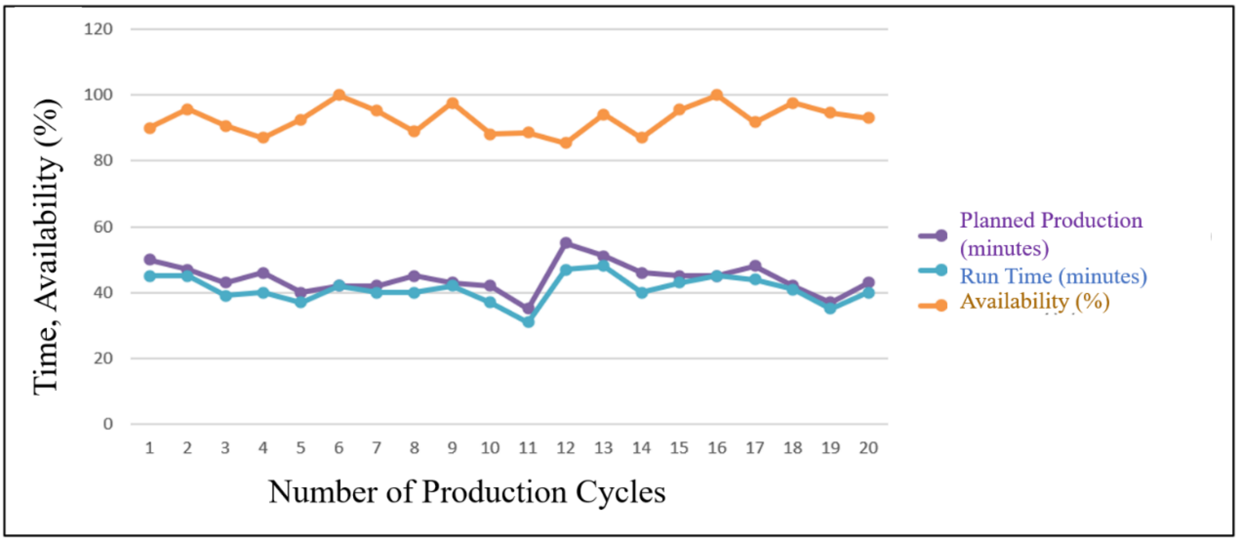


**Figure 9.**
Comparison of Planned Production Time, Run Time, and Availability.

From Figure 9, the Planned Production Time of each cycle ranges between 35–55 minutes. The maximum value is found in cycle 12 at 55 minutes, due to having only 5 minutes of planned break. The minimum value is in cycle 11 at 35 minutes, as it includes a planned break of 10 minutes within a 45-minute work cycle, which reduces the planned production time.

For Runtime, or the actual machine operating time after deducting downtime, the range is 31–48 minutes. The highest Runtime is observed in cycle 13 at 48 minutes, while the lowest Runtime is in cycle 11 at 31 minutes. These differences are caused by the varying amounts of downtime and planned breaks in each cycle.

The average Availability is higher than 90%, indicating that the system is highly reliable and ready for operation. The highest Availability of 100% occurs in cycles 6 and 16, which had no downtime at all. In contrast, the lowest Availability is in cycle 12 at 85.45%, resulting from 8 minutes of downtime, even though this cycle had the highest Planned Production Time in the dataset. Calculation of Performance based on Equation 2 is illustrated in Figure 10.

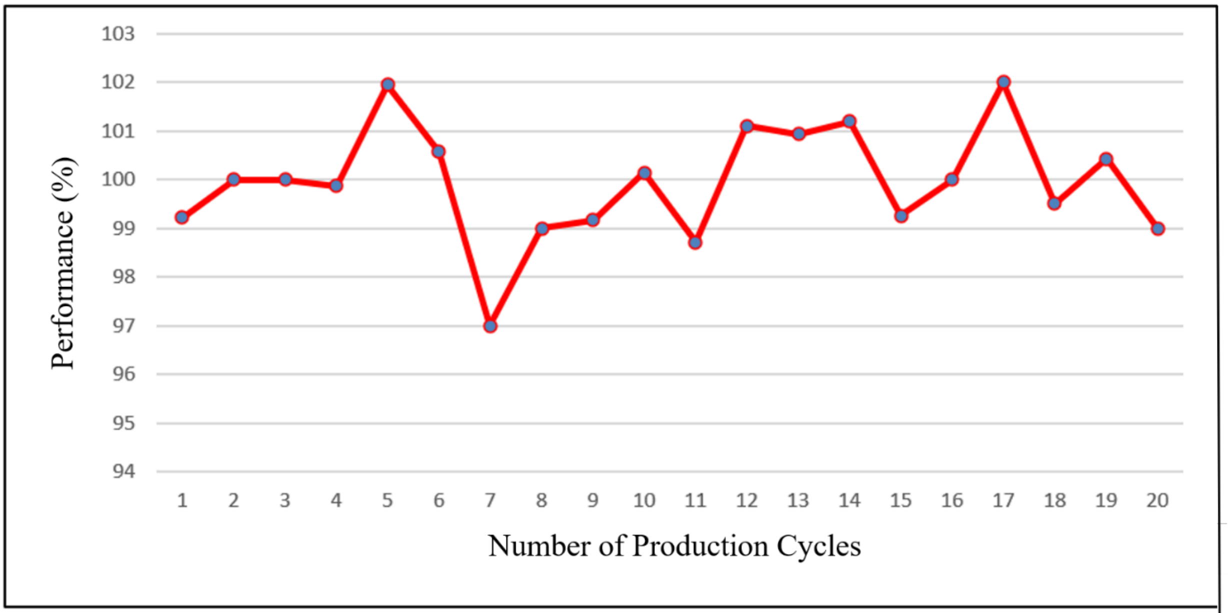


**Figure 10.**
Graph of Performance percentage for each work cycle.

From the calculation results, it was found that the Performance, which indicates the production speed relative to the standard time (ICT), remained high in almost all cases, ranging from approximately 97% to 102%. The highest Performance was observed in cycle 17 at 102%, showing that production during this cycle was faster than the defined standard. The lowest Performance occurred in cycle 7 at 97%, reflecting a slightly slower production speed compared to the standard.

Several cycles achieved Performance values above 100%, such as cycles 5, 12, 13, 14, 17, and 19, indicating production faster than the specified ICT. Meanwhile, most cycles achieved Performance values close to or equal to 100%, such as cycles 2, 3, 10, and 16, demonstrating production that precisely matched the standard. The calculation of Quality based on Equation 3 is illustrated in Figure 11.

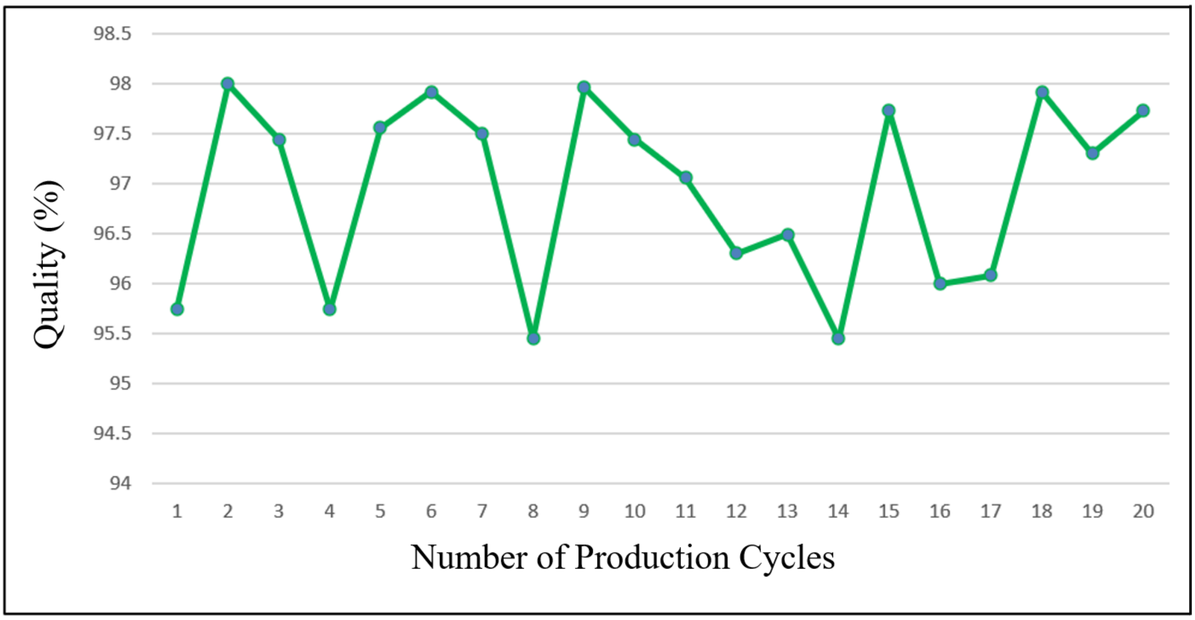


**Figure 11.**
Graph of Quality percentage for each work cycle.

From the calculation results, it was found that Quality, which represents the proportion of good products to the total number of products produced, ranged between 95.45% and 98%. The highest Quality was observed in cycle 2 at 98%, indicating the lowest defect rate in the production process. The lowest Quality was found in cycles 8 and 14 at 95.45%, reflecting a slightly higher defect rate compared to other cycles.

In most work cycles, the Quality value was above 96%, which can be considered very good. Several cycles showed similar values, such as cycles 5, 10, 11, 15, 18, 19, and 20, ranging from 97.06% to 97.92%, demonstrating consistency in product quality. The calculation of Overall Equipment Effectiveness (OEE) was carried out using Equation 4. Figure 12 presents a comparative graph of the calculated values of Availability, Performance, Quality, and OEE.

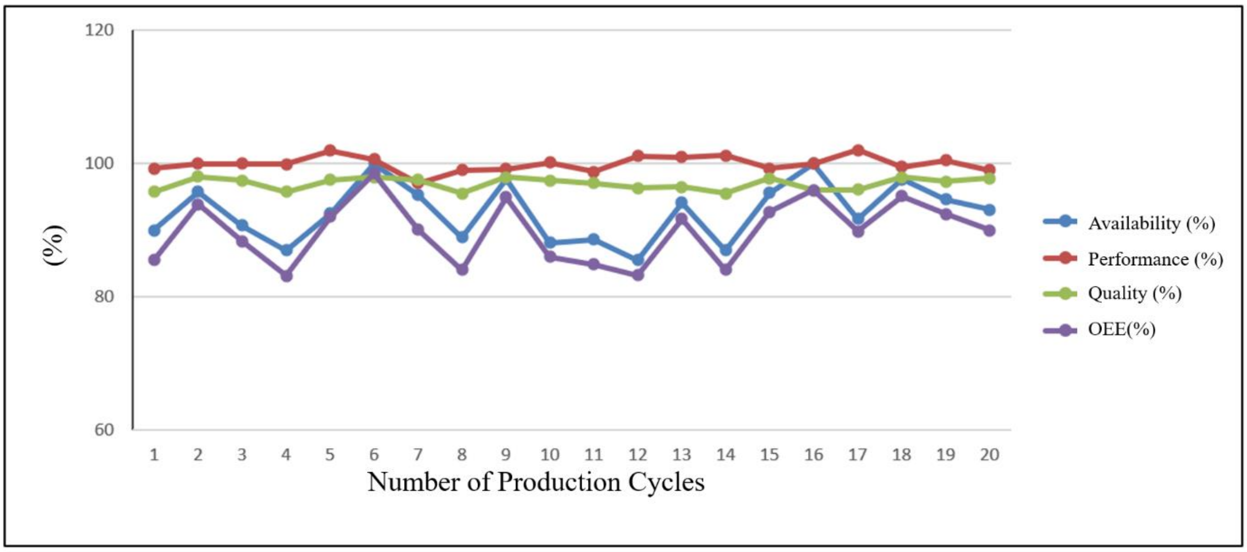


**Figure 12.**
Comparison of Availability, Performance, Quality, and OEE.

From the calculation results, the Overall Equipment Effectiveness (OEE) of the machine during the experiments ranged from 83.15% to 98.48%, with an average value above 90%. This indicates that the overall production process was highly efficient compared to industry standards (World Class > 85%).

The highest OEE was observed in cycle 6 at 98.48%, due to maximum Availability (100%), Performance above 100%, and Quality of 97.92%, demonstrating optimal operation without any downtime. The lowest OEE occurred in cycle 4 at 83.15%, primarily caused by low Availability of 86.96%, even though Performance and Quality remained high, highlighting the significant impact of downtime. Other cycles with OEE below 85% included cycles 8, 12, and 14, which resulted from Availability below 89% combined with Quality under 96%.

From the data, the average values of Availability, Performance, Quality, and OEE, as well as the maximum and minimum OEE values, were calculated and are presented in Table 2.

**Table 2.**
Calculation of the Average Values of Availability, Performance, Quality, and OEE, and the Maximum and Minimum OEE Values.

| Calculated Parameter | Calculated Value (%) |
|---|---|
| Average Availability | 92.67 |
| Average Performance | 99.95 |
| Average Quality | 96.94 |
| Average OEE | 89.80 |
| Maximum OEE | 98.48 |
| Minimum OEE OEE | 83.15 |

From the calculation results of Overall Equipment Effectiveness (OEE) during the experiments, the average Availability was found to be 92.67%, indicating that the production system had high readiness. Most of the planned production time was effectively utilized, and although occasional downtime occurred, it remained within a controllable range.

The average Performance was 99.95%, reflecting that the production speed was almost equal to or slightly above the defined standard (ICT), demonstrating consistent operational efficiency.The average Quality was 96.94%, indicating that most products were of good quality with a low defect rate. Consequently, the average OEE was 89.80%, which exceeds the typical industry benchmark for World Class performance, often set at 85% or higher.

## 4. Conclusion

This study developed a production system for Digital Manufacturing applications in Mechatronics and evaluated its performance using the Overall Equipment Effectiveness (OEE) metric. The system operated under conditions where the production cycle time did not exceed one hour per run, and the Ideal Cycle Time (ICT) per unit was set at one minute. A total of 20 production cycles were conducted to assess the three main OEE components: Availability, Performance, and Quality, as well as the overall OEE of the system.

Analysis of the collected data indicated that the average Availability was 92.67%, reflecting a high level of machine readiness. The highest Availability was observed in cycles 6 and 16, both achieving 100% due to the absence of unplanned downtime. In contrast, the lowest Availability occurred in cycle 12 at 85.45%, attributed to the maximum downtime of eight minutes. Although this cycle had the longest Planned Production Time of 55 minutes, the excessive downtime reduced the actual runtime, significantly impacting Availability. It was further observed that cycles with low Availability were often associated with extended Planned Breaks combined with unplanned downtime. The average Performance across all cycles was 99.95%, indicating production speeds close to or exceeding the established ICT. Cycles exceeding 100% Performance, such as cycles 5 (101.95%), 12 (101.11%), 13 (100.94%), 14 (101.20%), 17 (102%), and 19 (100.43%), demonstrated efficient production management and minimized internal process losses. The lowest Performance was recorded in cycle 7 at 97%, which, while still high, reflected slightly slower production than the standard. Quality performance averaged 96.94%, indicating that the majority of produced units met quality standards with low defect rates. The highest Quality was observed in cycle 2 at 98%, demonstrating effective quality control, while the lowest Quality occurred in cycles 8 and 14 at 95.45%, reflecting slightly higher defect rates, yet remaining within acceptable industrial standards. The overall OEE averaged 89.80%, exceeding the World Class benchmark (>85%), demonstrating high production effectiveness. The cycle with the highest OEE was cycle 6 at 98.48%, resulting from 100% Availability, Performance above 100%, and Quality at 97.92%, representing a near "ideal" production state. The lowest OEE occurred in cycle 4 at 83.15%, primarily due to reduced Availability of 86.96%, despite high Performance and Quality. Additional cycles with OEE below 85%, including cycles 8, 12, and 14, were also linked to low Availability and Quality below 96%.

Overall, the production system demonstrated consistently high performance in Availability, Performance, and Quality. Its key strengths were the stable Performance and Quality across almost all production cycles. The main area for improvement lies in reducing unplanned downtime during cycles with lower Availability, which directly affects OEE. By optimizing downtime and controlling Planned Break durations, the OEE in several cycles could approach the maximum observed in cycle 6 at 98.48%. The observed fluctuation between the highest OEE (98.48%) and lowest (83.15%) indicates opportunities to improve real-time operation management and minimize losses in production time.

## References


[1] NECTEC, "Industry 4.0 assessment," Sustainable Manufacturing Center (SMC), 2025. https://www.nectec.or.th/smc/services-i4-0-assessment/

[2] IoT Analytics, "Smart manufacturing learnings from digital transformation initiatives," IoT Analytics, 2025. https://iot-analytics.com/smart-manufacturing-learnings-from-ongoing-digital-transformation-initiatives/

[3] W. Ratchatasomboon, "Robotics and industrial automation experimental kits througha IIOT communication system," *Vocational Education Central Region Journal,* vol. 7, no. 1, pp. 1–17, 2023.

[4] S. Khwanmuang, "Programmable logic controller training set," *Journal of Industrial Education,* vol. 20, no. 3, pp. 80–90, 2021.

[5] P. Sritam, N. Buhnga, W. Boonperm, and S. Deesom, "Automatic material sorting machine on conveyor belt controlled by PLC," *Journal of Farm Engineering and Automation Technology,* vol. 7, no. 1, pp. 49–59, 2021.

[6] P. Korcharoen, "Short-range wireless communication with visible light: Technology, development, and technology-driven," *NBTC Journal,* vol. 1, no. 1, pp. 526–549, 2016.

[7] S. Chattunyakit *et al.*, "AI and IoT-enabled workpiece sorting system using mini-PLC for industrial automation," in *Proceedings of the 2024 International Conference on Advanced Mechatronic Systems (pp. 526–549). Shiga, Japan*, 2024, doi: https://doi.org/10.1109/ICAMechS63130.2024.10818841.

[8] W. Waluyo, A. Widura, and W. A. Purbandoko, "Energy-saving in air conditioners using PLC control and the SCADA monitoring system," *ECTI Transactions on Electrical Engineering, Electronics, and Communications,* vol. 2014, no. 1, pp. 22-31, 2022. https://doi.org/10.37936/ectieec.2022201.246095

[9] S. Kongsinthu, A. Singchan, S. Damnui, and N. Suksong, "Design of an automatic color sorting conveyor system using Arduino color module," *Journal of Research and Innovation,* vol. 1, no. 2, pp. 56–68, 2018.

[10] Y. Krueharnchanpong, S. Sengiamphong, A. Senanarong, and P. Sutthiwari, "Design and development of a pneumatic harvesting tool for oil palm (Elaeis guineensis Jacq.)," *Thai Agricultural Research Journal,* vol. 29, no. 1, pp. 12–20, 2011.

[11] P. Kotchapoom, A. Sereepattanannon, and T. Namhomchan, "Light distribution test set controlled by stepper motor," *Eastern Asia University Journal of Science and Technology,* vol. 6, no. 2, pp. 110–116, 2014.

[12] T. Phayommai, W. Silabut, M. Thamma, W. Wibooncharoen, and S. Wangkhuntod, "Embedded system for automatic door control with recognizing faces," *Huachiew Chalermprakiet Science and Technology Journal,* vol. 7, no. 1, pp. 63–72, 2021.

[13] T. Ouypornkochagorn, "Spy OEE: A novel method for getting OEE by operating time characteristic," *Rompruek Journal Krirk University,* vol. 30, no. 1, pp. 1–24, 2012.

[14] C. D. Promotion, *Overall equipment effectiveness (OEE) templates: Blank sheets*. United States: Independently Published, 2019.

[15] L. d. C. Ng Corrales, M. P. Lambán, M. E. Hernandez Korner, and J. Royo, "Overall equipment effectiveness: Systematic literature review and overview of different approaches," *Applied Sciences,* vol. 10, no. 18, p. 6469, 2020. https://doi.org/10.3390/app10186469

[16] T. Boonraksa *et al.*, "Performance analysis of a low-cost automatic single-dispenser drinking water filling machine controlled by a programmable logic controller," *Journal of Engineering and Digital Technology,* vol. 12, no. 1, pp. 75–84, 2024.