A MES Application for OEE Improvement in Plastic Injection Facilities

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Abstract: *In plastic injection and plastic welding processes, the inability to accurately classify machine downtimes, the lack of visibility regarding performance discrepancies between shifts, and the reliance on largely manual methods for operator tracking hinder the sustainable improvement of Overall Equipment Effectiveness (OEE). Furthermore, the retention of pro- duction and energy consumption data in isolated systems complicates integrated performance evaluation.*

In this study, the HBS MES system, developed by the in-house engineering team of Pleksan A.S. and fully integrated with HBS ERP, is examined within the scope of a field application aimed at real-time production tracking, performance analysis, and energy consumption reporting in plastic injection lines. As of 2025, HBS MES is actively used in its V1 version across three different plastic manufacturing enterprises; this paper exemplifies a facility predominantly focused on plastic injection.

The paper presents the system architecture, data collection logic, modeling of production and downtime events, the approach to calculating OEE and its sub-metrics, and user interface components in detail. As a result of the implementation in the studied facility, an improvement of approximately 25% in production quantities was reported, particularly during night shifts, and the mechanisms underlying this improvement are discussed. The findings demonstrate that MES solutions integrated with machine-embedded data collection modules can provide measurable productivity gains even in small and medium-sized enterprises.

KEYWORDS: *MES, OEE, PLASTIC INJECTION, DIGITAL TRANSFORMATION, REAL-TIME MONITORING*

1 Introduction

Plastic injection and plastic welding processes play a critical role in many sectors, such as automotive, white goods, packaging, and machinery manufacturing. In such production lines, efficiency is often managed through operator experience and instantaneous decisions within the shift, while reasons and durations of downtimes are tracked via paper forms or scattered electronic spreadsheets in most enterprises. Energy consumption data is frequently kept in separate monitoring systems, preventing integrated analysis with production data. This situation weakens the reliability of OEE calculations and impedes data-driven improvement efforts.

Manufacturing Execution Systems (MES) aim to provide enterprises with real-time visibility, traceability, and performance analysis by processing data collected from the field. In plastic injection processes, MES applications manage production resources online, shortening processing times and reducing operating costs [1, 3]. Furthermore, literature emphasizes that real-time monitoring systems significantly increase OEE values and provide managers with instantaneous decision-making capabilities [4]. Specifically, the automatic detection of machine states (running, planned downtime, unplanned downtime, setup, quality rejection, etc.) and the accurate calculation of OEE components are fundamental elements of continuous improvement and lean manufacturing practices.

The enterprise adopted a strategy of developing its own unique solution to overcome the flexibility constraints of existing package programs and to fully meet facility-specific needs, rather than acquiring a ready-made off-the-shelf solution.

In this study, the HBS MES system, developed for plastic injection and plastic welding machines, is technically examined through a real-world facility application. HBS MES employs a three-layer structure consisting of HiLog data collection modules connected to machines, an application server, and a Blazor/SignalR-based web interface, operating in integration with HBS ERP. The focus of the study is not only to introduce the system’s functions but also to model and examine the performance gains obtained in the field from an engineering perspective.

The remainder of the paper first defines the industrial environment and system requirements, followed by an explanation of the HBS MES architecture and data model. Subsequently, the approach to calculating OEE and sub-metrics is presented, and results obtained from the field application in a selected plastic injection facility are provided. The final section discusses the system’s limitations, strengths, and areas for future development.

2 Industrial Environment and System Requirements

2.1 Facility and Production Process

HBS MES is primarily designed for use in multi-shift production facilities operating with plastic injection and plastic welding machines. Typically, in these facilities:

- Production is carried out on a 24-hour basis, in day and night shifts,
- Multiple injection and welding machines operate in parallel on the same line,
- Work orders are opened via HBS ERP, and machine/mold pairings are planned through this system,
- Production quantities, scrap amounts, and downtime durations are still reported via semi-manual methods in many locations.

During night shifts, the limited availability of management and engineering staff leads to insufficient monitoring of operator behaviors and machine usage habits. This situation can result in significant efficiency differences between day and night shifts on the same machinery fleet.

2.2 Functions Expected from MES

The fundamental functions expected from the MES system for the enterprises in question can be summarized as follows:

- Monitoring real-time running/stopped status on a machine basis,
- Automatic or semi-automatic classification of downtimes under categories such as *planned maintenance*, *unplanned breakdown*, and *setup/mold change*,
- Calculation of OEE and sub-performance metrics on the basis of shift, machine, station, and operator,
- Identification of operators via RFID cards and generation of operator-based performance reports,
- Automatic transfer of work orders to the MES environment through integration with HBS ERP and feedback of realized production data to the ERP side,
- Provision of user interfaces to support downtime planning, maintenance organization, and production planning processes,
- Reporting of production and energy consumption data on a common data model [6].

Based on these requirements, monitoring, reporting, planning, production management, and quality management modules have been designed within HBS MES.

3 HBS MES System Architecture

3.1 General Architectural Structure

HBS MES consists of three fundamental layers:

1. **Machine Layer:** HiLog data collection modules connected to plastic injection and plastic welding machines monitor digital signals on the machine (running/stopped, mold open/close, fault signals, energy measurements, etc.) and transmit them to the upper layer on an event-driven basis.
2. **Application Server:** Data received from HiLog modules is acquired, processed, and recorded in a relational database via services running on the server side. This layer manages the relationships between work orders, machines, stations, operators, and downtime records.
3. **User Interface Layer:** HBS MES offers a Blazor-based web interface and real-time data updates via SignalR. Users access dashboard screens, Gantt charts, downtime planning, and performance reports via a browser.

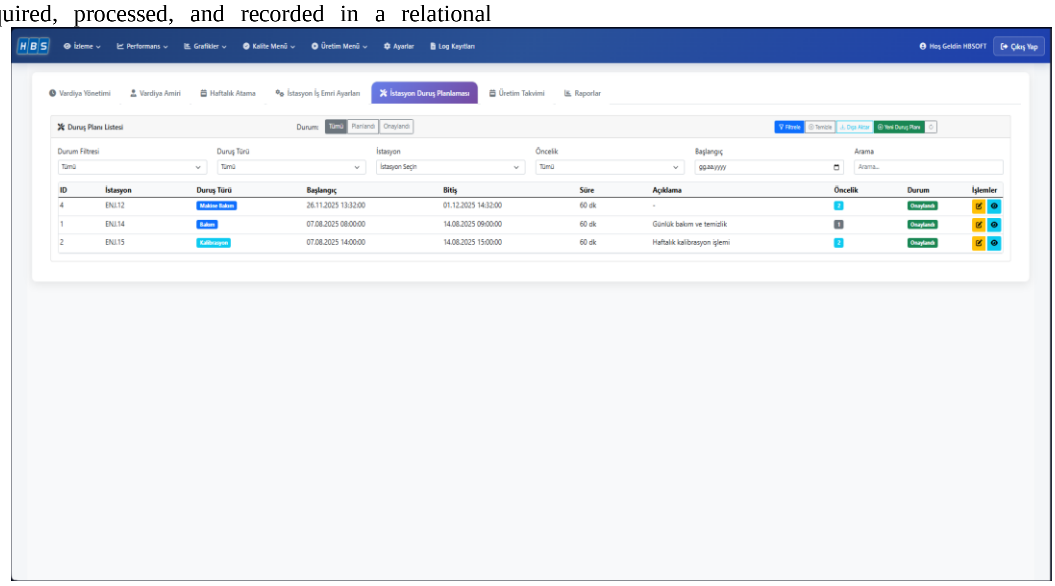

Figure 1: *Station downtime planning screen; planning, prioritizing, and approving maintenance and calibration downtimes.*

This structure meets the real-time requirement at the machine level while providing an integrated production management flow with the ERP [2, 7].

Hardware and Communication Infrastructure

HiLog modules are connected to machine control panels to monitor relevant digital and analog signals. Data such as machine status, cycle completion signals, fault information, and energy consumption are packaged and sent to the server the moment the event occurs. Ethernet-based TCP/IP communication is preferred for data transmission in accordance with the enterprise infrastructure.

The service layer running on the server side records incoming events with timestamps and matches them with machine and work order information. Thanks to the event-driven data collection approach, time-based calculations can be performed accurately even for machines with variable cycle times or frequent stop-and-go operations [5].

3.2 Software Modules and User Interfaces

The prominent modules within HBS MES are as follows:

- **Instant Monitoring:** Monitoring of instantaneous states (running, stopped, setup, breakdown, etc.) on a machine and station basis, station lists, and summary indicators.
- **Downtime Planning:** Planning of maintenance, calibration, and other planned downtimes on a station basis, approval processes, and prioritization.
- **Gantt Charts:** Visualization of machine activities on a time axis per shift; display of running, downtime, and setup blocks on a single screen. Combining multiple work orders on the same activity facilitates planning and analysis.
- **Machine Performance Dashboard:** Presentation of OEE components and related time/quality metrics on a machine basis via donut charts and completion indicators.
- **Operator and Work Order Cards:** Display of operator name, work order quantity, produced quantity, elapsed time, and estimated completion time on a single card.

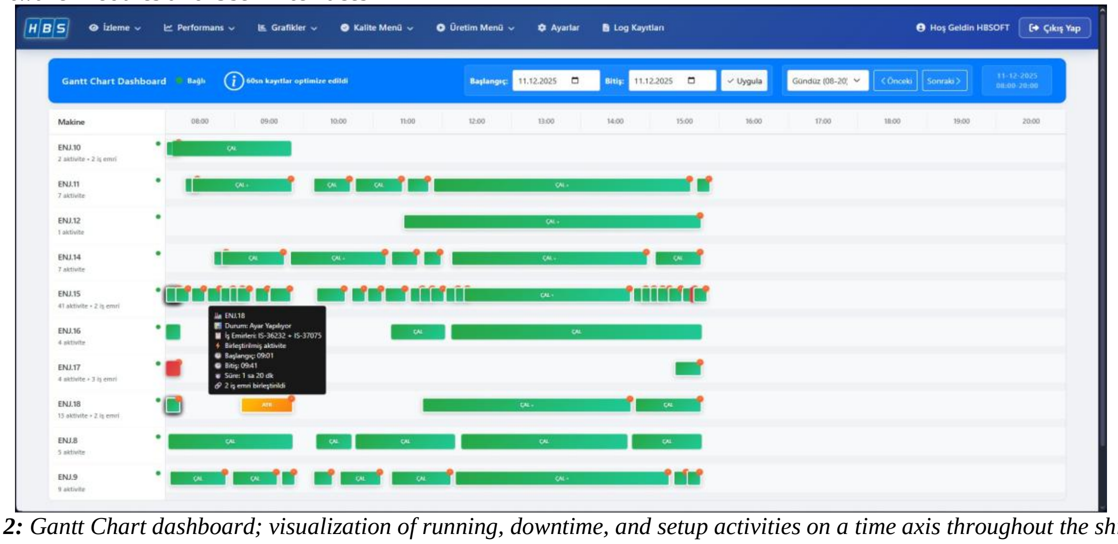

Figure 2: *Gantt Chart dashboard; visualization of running, downtime, and setup activities on a time axis throughout the shift on a machine basis.*

These screens serve as decision support tools not only for executive-level users but also for shift supervisors and maintenance teams.

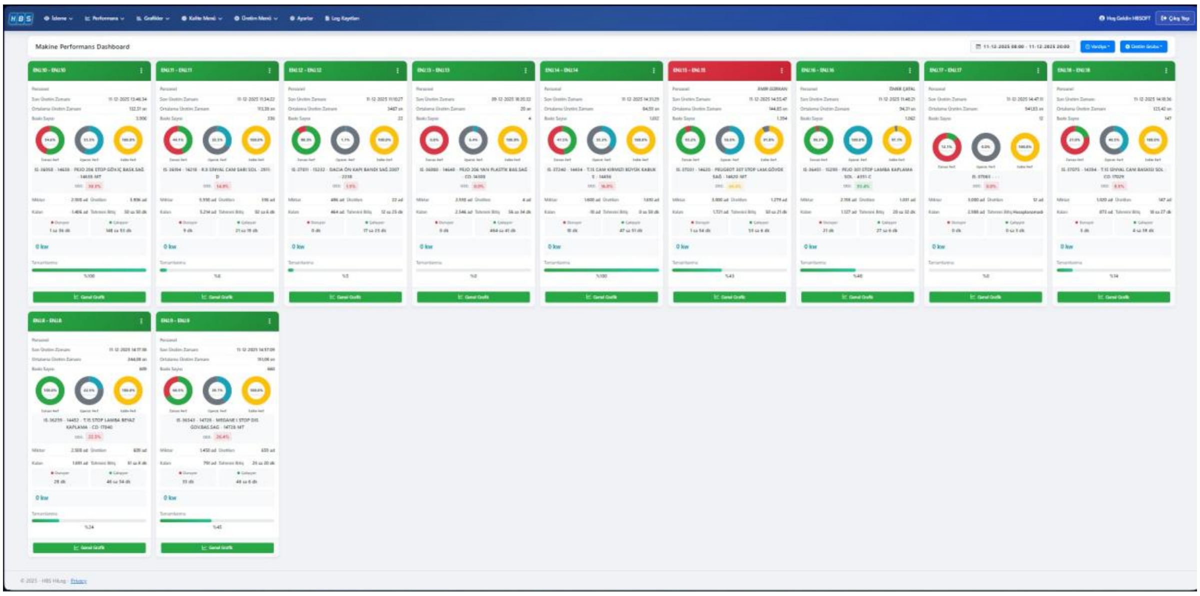

Figure 3: Machine performance dashboard; summary of machine status with OEE components and completion indicators.

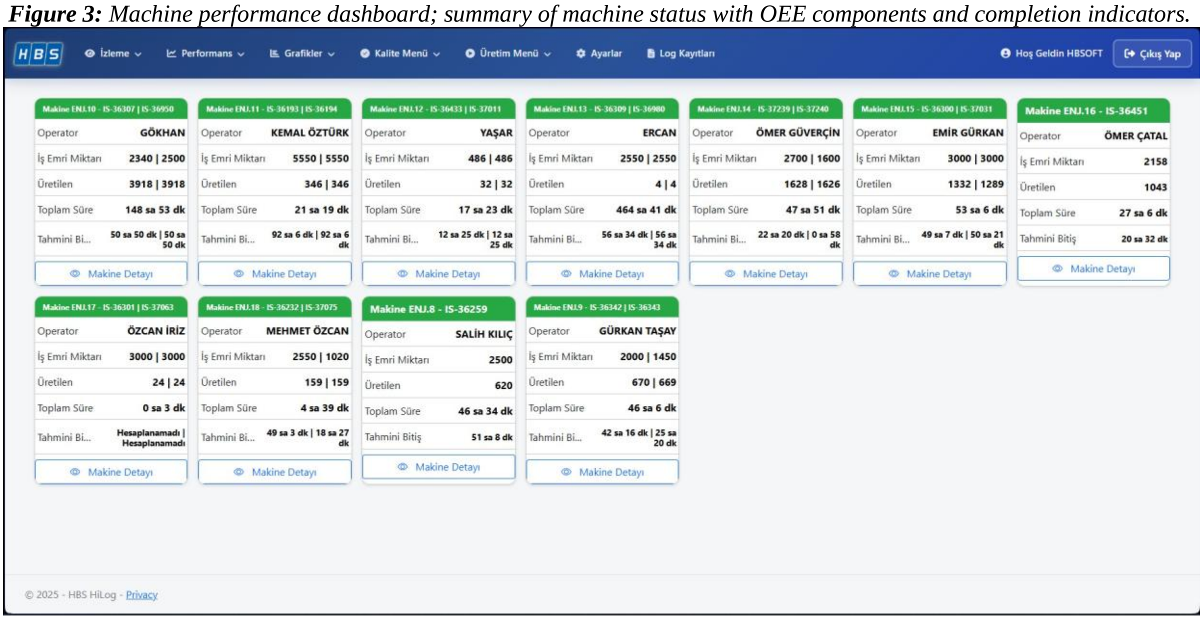

Figure 4: Operator and work order cards; monitoring production performance and estimated completion times on an operator basis. Real-Time Data Processing

Thanks to the SignalR-based web interface, changes in machine and station statuses are reflected on user screens with latencies in the order of seconds. The event-driven data model ensures that for each machine:

- Activity start and end times,
- Activity type (production, planned downtime, unplanned downtime, setup, etc.),
- Associated work order (multiple work orders if necessary),
- Relevant operator are stored as single records. Thus, both Gantt charts and OEE calcula- tions can be generated based on the same data model [5].

4 Data Model and Performance Metrics

4.1 Data Collection and Event Types

In the HBS MES data model, the fundamental monitoring unit is the concept of *activity* [7]. Each activity possesses the following fields for a specific station or machine:

- Start timestamp,
- End timestamp,
- Activity type (production, planned downtime, unplanned downtime, setup, calibration, etc.),
- Relevant work order or work orders,
- Relevant operator (based on RFID card),
- Associated energy consumption or count information, if applicable.

The data collection logic is based on opening a record when an event occurs, rather than fixed-period sampling. When production or a stop occurs, the event is monitored via the HiLog module, and the occurrence information is transmitted to the server via the service. This allows accurate time-based calculations even for machines with variable cycle times or those that stop frequently or malfunction often.

The main variables collected include:

- Machine cycle counts and cycle times,
- Machine downtime durations and downtime types,
- Machine setup and calibration times,
- Energy consumption data,
- Downtime records on a line and station basis,
- Operator and machine/work order pairings.

4.2 Definition of OEE and Sub-Metrics

Overall Equipment Effectiveness (OEE) is widely defined in the literature as the product of three basic components: availability, performance, and quality [8, 9]. In this study, HBS MES data has been evaluated based on the classical literature definition [10].

Availability (A), where T_{plan} is the planned production time and T_{downtime} is the unplanned downtime duration, is defined as:

$$A = \frac{T_{plan} - T_{downtime}}{T_{plan}}$$

(1)The performance component (P) for the net operating time T_{net}, theoretical cycle time t_{cycle}, and total produced quantity N_{total} is expressed as:

$$P = \frac{N_{total}\, t_{cycle}}{T_{net}}$$

(2) The quality component (Q) for the total produced quantity N_{total} and the quantity of good products N_{good} is:

In this case, OEE is calculated as:

$$Q = \frac{N_{good}}{N_{total}}$$

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

Within HBS MES, these components are calculated on the basis of shift, machine, station, and work order, and presented to the user on dashboard screens.

The system also produces derived indicators such as Time Performance, Quality Performance, and Operator Performance according to enterprise needs. While time and quality performance are directly related to the OEE components summarized above, operator performance is normalized by taking into account the production, downtime, and quality profile that occurred during the shifts the operator was on duty. In this paper, the operator performance index is treated as a decision support indicator rather than being detailed with its formula. As emphasized in the literature [4], the systematic classification of downtime reasons and the monitoring of operator performance play a critical role in detecting hidden efficiency losses.

4.3 Statistical Analysis and Decision Support

In the discussed V1 version of HBS MES, decision support functions are presented through reporting screens that allow the enterprise to evaluate collected cycle and downtime data using classical statistical methods. Users can observe trends in production quantities and OEE components over time, rank downtime reasons according to their share in total time, and make basic comparisons between shifts.

In the machine performance dashboard, status indicators are presented for each machine via three donut charts related to time, performance, and quality, based on threshold values (e.g., red for below 60%, yellow for 60%–80%, green for above 80%). Thus, shift supervisors and maintenance teams can see on a single screen which machines require rapid intervention.

5 Field Application: HBS MES in a Plastic Injection Facility

5.1 Facility Description and Installation Process

The field application detailed in this study was carried out in a facility producing with plastic injection machines. The facility houses multiple injection machines of different tonnages and plastic welding stations. Production is carried out in a three-shift order; performance drops and lack of downtime records, especially during night shifts, were identified as a significant problem by the enterprise.

Within the scope of the HBS MES installation:

- HiLog modules were connected to the control panels of selected machines,
- Machine signals (running, stopped, breakdown, cycle) were determined and assigned to HiLog inputs,
- Work order, product, and customer definitions and machine lists on the HBS ERP side were synchronized,
- Operators were defined in the system with RFID cards, and the use of these cards at shift entries/exits was ensured.

In the first stage, the system was used mostly for monitoring purposes; a short adaptation process was undergone for operators and shift supervisors to get used to the screens, select downtime reasons correctly, and improve data quality.

5.2 Experimental Design and Evaluation Approach

In the evaluation of the field application, the pre-MES and post-MES periods were compared. The enterprise specifically aimed to reduce fluctuations in production quantities during the night shift and to close performance gaps between shifts.

The evaluation analyzed:

- Night shift production quantities and downtime profiles in the pre-MES reference period,
- Night shift production quantities and downtime profiles for the same machines in a period of similar length after MES was commissioned,
- OEE components and scrap rates on a shift basis.

Enterprise data has been shared using normalized indicators observing commercial sensitivities within the scope of company permission, in order to substantiate the effects of the field application. A normalized comparison for a sample night shift is shown in Table 1. Here, the pre-MES period is scaled as 1.00, and the post-MES period is scaled according to the improvement reported by the enterprise.

Table 1: *Normalized comparison of night shift production performance (sample machine group).*

Indicators	Pre-MES	Post-MES	Change [%]	Average
production quantity (normalized)	1.00	1.25	+25	

Table 1 shows that there was an increase of approximately 25% in average production performance on a normalized basis during the night shift after the system was commissioned. Furthermore, according to field observations and enterprise evaluations, improvements were observed in downtime management and process stability. Obtained Results

According to enterprise feedback and HBS MES reports, after the system was commissioned, the following were observed during night shifts:

- An increase of approximately 25% in average production quantities per machine,
- Improvement in maintenance and setup organization thanks to the transparency of down- times based on reason and duration,
- Visibility of performance differences between operators and, consequently, more systematic execution of feedback and shift management processes.

Thanks to Gantt charts and station downtime planning screens, maintenance and setup downtimes were planned in a more controlled manner, reducing unnecessary waiting times within the shift. Since work order quantity, produced quantity, total time, and estimated completion time for each operator could be seen on a single screen via operator and work order cards, shift supervisors were able to make load balancing and intra-shift intervention decisions more quickly. The 25% production increase reported in night shifts is not solely due to HBS MES; however, the transparency provided by the system, the correct classification of downtimes, and the activation of operator-based tracking can be evaluated as the main contributing components of the observed improvement.

6 Discussion

6.1 Evaluation of Gains

The field application is particularly noteworthy in the following respects:

- Thanks to HiLog modules directly connected to the machine, production and downtime data are collected with minimum dependence on operator input, which ensures high accuracy in the calculation of OEE and sub-metrics [4].
- Gantt charts and the machine performance dashboard provide a strong visual ground for shift-based performance analysis. Managers and engineers can quickly see which machines have bottlenecks and in which time intervals downtimes are concentrated.
- Thanks to RFID-based operator cards, performance differences between operators become tangible; this is used both in identifying training needs and in feedback processes.
- Since the installation is designed as a solution embedded in the existing machine and ERP infrastructure, the commissioning process remains relatively short for enterprises.

These gains are consistent with OEE improvements reported in the literature with MES applications. In particular, the transparency provided by the bidirectional integration with HBS ERP in the field application [2, 7] coincides with findings in other studies [1, 2, 3]. This synchronization provided via modern APIs minimizes deviations in planning processes. A noteworthy point here is the reporting of a production increase in the order of 25% in night shifts with the first MES application in an enterprise that initially had limited systematic data collection infrastructure. System Limits and Constraints

HBS MES has currently been applied and verified mainly in discrete manufacturing processes such as plastic injection and plastic welding. For continuous processes (chemistry, cement, refinery, etc.), the data model and user interfaces may require additional adaptations.

Although the system architecture is designed to support a large number of machines in terms of scalability, current field applications are limited to medium-sized facilities. In very large machinery fleets, additional optimization steps may be needed in matters such as database size, network traffic, and dashboard performance.

From an analytical perspective, the discussed version of HBS MES primarily offers decision support mechanisms based on classical statistical analyses and threshold values. Functions such as predictive maintenance, advanced machine learning models, and automatic root cause analysis are potential areas for development that can be added to the core structure of the system.

6.2 Application Perspective

Different studies in the field of MES and OEE improvement report efficiency increases at various rates [1, 3]. The night shift production increase in the order of 25% reported in this study indicates that the impact of the initial MES application can be high, especially in enterprises with limited systematic data collection infrastructure at the outset.

However, this evaluation, based on a single facility and a specific period, is not sufficient for generalization. More comprehensive field studies comparing different sectors, different MES solutions, and different organizational structures will strengthen the body of knowledge in this field.

7 Conclusion and Future Work

In this study, the application of HBS MES in a production facility operating with plastic injection and plastic welding machines was technically examined; the system architecture, data model, user interfaces, and field results were presented within a holistic framework. Thanks to machine- embedded HiLog data collection modules, an event-driven data model, and Blazor/SignalR-based web interfaces, the enterprise achieved performance visibility on a machine, shift, and operator basis in a short time.

In the field application, an improvement of approximately 25% in production quantities was reported, especially during night shifts; this improvement was associated with the visibility of downtimes, the strengthening of planned maintenance organization, and the activation of operator-based performance tracking. The results obtained demonstrate that MES solutions that are appropriately designed and integrated at the correct point can provide tangible productivity increases even in small and medium-sized facilities.

Within the scope of future work, it is suggested to:

- Examine HBS MES applications in different sectors (e.g., metal machining, assembly lines) and perform cross-comparisons,
- Develop data analytics and machine learning models focused on predictive maintenance and process optimization on the collected data,
- Integrate energy efficiency-oriented metrics more strongly into the system and define energy-based OEE-like indicators,
- Address indicators used in operator performance measurement together with human factors, ergonomics, and training dimensions.In conclusion, the HBS MES example demonstrates that meaningful contributions can be made to the field of production efficiency from both academic and industrial perspectives with domestic software and hardware solutions.

References

[1] Bălan, E. L. (2022). Improving a plastics injection process by using an efficient production management system. *Conference Proceedings of the Academy of Romanian Scientists, PRODUCTICA ScientiFIc Session*, Vol. 14, No. 1, pp. 105–113.

[2] Oman, S., Leskovar, R., Rosi, B., and Baggia, A. (2017). Integration of MES and ERP in supply chains: Effect assessment in the case of the automotive industry. *Tehnički vjesnik – Technical Gazette*, 24(6), 1889–1896. doi:10.17559/TV-20160426094449.

[3] Mahmoud, M. I., Ammar, H., Hamdy, M. M., and Eissa, M. H. (2015). Production operation management using manufacturing execution systems (MES). In *Proceedings of the 11th Inter- national Computer Engineering Conference (ICENCO)*. doi:10.1109/ICENCO.2015.7416334.

[4] Hedman, R., Subramaniyan, M., and Almström, P. (2016). Analysis of critical factors for au- tomatic measurement of OEE. *Procedia CIRP*, 57, 128–133. doi:10.1016/j.procir.2016.11.023.

[5] Theorin, A., et al. (2015). An event-driven manufacturing information system architecture. *IFAC-PapersOnLine*, 48(3), 547–554. doi:10.1016/j.ifacol.2015.06.138.

[6] Chen, X., Nophut, C., and Voigt, T. (2020). Manufacturing execution systems for the food and beverage industry: A model-driven approach. *Electronics*, 9(12), 2040. doi:10.3390/electronics9122040.

[7] International Society of Automation (ISA) / IEC. *Enterprise-Control System Integration – Part 1: Models and Terminology* (ANSI/ISA-95.00.01 / IEC 62264-1). (Standard).

[8] International Organization for Standardization (ISO). *Automation systems and integration – Key performance indicators (KPIs) for manufacturing operations management – Part 2: DeFInitions and descriptions* (ISO 22400-2:2014). (Standard).

[9] Nakajima, S. (1988). *Introduction to TPM: Total Productive Maintenance*. Productivity Press. ISBN: 978-0-915299-23-2.

[10] Schiraldi, M. M., and Varisco, M. (2020). Overall equipment effectiveness: Consis- tency of ISO standard with literature. *Computers & Industrial Engineering*, 145, 106518. doi:10.1016/j.cie.2020.106518.