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IMPLEMENTATION OF A DOBOT MAGICIAN ROBOTIC ARM IN A DIDACTIC LEAN LINE: A REALISTIC SIMULATION-BASED APPROACH

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ABSTRACT

This work explores the enhancement of the Earmalean line in order to increase accessibility, operational efficiency, and educational impact. FlexSim is used to model system behavior, process interactions, and human-machine collaboration in a dynamic and visual environment. The simulation incorporated realistic process logic, including part flows, workstation interactions, stock management, and operator tasks, allowing the testing of multiple what-if scenarios under controlled conditions. FlexSim's 3D modeling capabilities and integrated analytics tools enabled the evaluation of key performance indicators such as cycle time, throughput, resource utilization, and work-in-process inventory. Data-driven modeling enabled realistic scenario testing, including automated logistics and human-robot collaboration. The results underline the value of integrating smart technologies into didactic systems and open pathways for future development toward a connected and adaptive learning platform.

1 INTRODUCTION

The rise of Industry 5.0 has redefined the relationship between humans and machines, emphasizing collaboration, flexibility, and sustainability. Lean manufacturing principles continue to play a key role in improving industrial efficiency. In this context, didactic assembly lines serve as experimental platforms where engineering students can explore real-world production dynamics.

This project addresses the modernization of a flexible learning line -ErmaLean- used for training in Lean Six Sigma and Industry 4.0 technologies. It focuses on translating theoretical knowledge into practice through digital experimentation and incremental innovation.

2 METHODOLOGY

The study was conducted using the ErmaLean didactic line, which includes five assembly stations, a supervision system with Tulip ERP, local and central storage units, and integrated IoT-based tracking technologies. The existing setup was modeled in FlexSim using operational data collected during hands-on workshops with student operators. The overall research methodology is summarized in Figure 1.

Three simulation scenarios were designed:

1. The current manual configuration,
2. An automated logistics system replacing the human logistician with conveyors and sensors,
3. A collaborative robotic integration (Dobot Magician) to assist a bottleneck station.

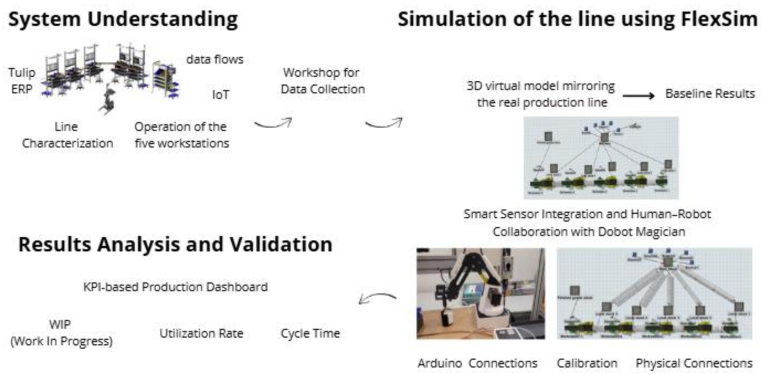

Figure 1: Simulation methodology applied to the ErmaLean didactic line.

Arduino-controlled interfaces were developed to enable interaction between the robot and operators. Custom mechanical supports were designed using 3D printing to ensure precision during robotic tasks. Simulations were performed under fixed daily workloads to evaluate key performance metrics across configurations.

3 RESULTS AND DISCUSSION

Simulation of the initial configuration highlighted inefficiencies in the system, with early workstations frequently idle and downstream stations operating under high load. A clear bottleneck emerged at one critical station, disrupting the overall production flow and increasing operator movement across the line as revealed by workstation utilization rates, idle time analysis, and logistical movement tracking.

The introduction of conveyor-based automation helped streamline material transport, resulting in improved productivity and smoother task transitions as indicated by reductions in cycle time, enhanced throughput, and lower physical strain on operators. However, the increased throughput also led to a slight rise in work-in-process inventory suggesting a more intensive use of system capacity and the need for inventory control.

In the final scenario, integrating a collaborative robot at the bottleneck station significantly reduced handling time and alleviated operational pressure at that point with improvements in task distribution and flow balance across stations. This led to a more balanced distribution of tasks across the line and enhanced flow consistency. While the overall production improvement was moderate, the pedagogical benefit of showcasing human-robot collaboration within an industrial learning environment proved highly valuable.

4 CONCLUSION

This project demonstrates that even in a didactic context, digital transformation principles can significantly enhance system performance and learner engagement. The implementation of automated logistics and collaborative robotics not only improved throughput but also introduced students to advanced industrial practices.

Future work may focus on transitioning from passive simulations to a dynamic digital twin, capable of real-time interaction and AI-driven optimization. The potential integration of mobile service robots and machine learning for quality control offers further opportunities to extend the pedagogical and technical scope of the platform.

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