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Improving On-Time Delivery in a Metalworking Company through: 5S, SMED and Jidoka

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Abstract

In the Peruvian metalworking sector, on-time delivery (OTD) continues to be a structural challenge due to the high variability of processes, poor operational standardization, and reliance on operator-based practices. These conditions particularly affect industries such as mining and construction, where delays in repairing hydraulic cylinders generate significant costs due to downtime and lost productivity. This study seeks to improve OTD performance at a metalworking company in Lima dedicated to the repair and manufacture of hydraulic cylinders, whose initial compliance level is 43%. The diagnosis identified three main gaps: deficiencies in order and discipline, lack of a systematic setup procedure, and unstable control of the cooling process in chrome plating. To address these limitations, an improvement model based on Lean Manufacturing was designed, integrating 5S to restore operational discipline, SMED to reduce variability in setup times, and Jidoka through an automatic water level control system to stabilize the critical cooling stage. The proposal was validated through event simulation in Arena, complemented by a simulation modeled in DWSIM, which allowed for the evaluation of production flow behavior and the effect of automation on reducing variability. The main contribution of the study is to demonstrate that the joint application of Lean tools can transform an unstable and reactive process into a standardized and repeatable flow, with less rework and greater reliability.In the optimized scenario, the OTD increased from 43.2% to 83%, confirming the effectiveness of the model and the relevance of autonomous control for improving delivery punctuality in metalworking environments.

Keywords
On-Time Delivery (OTD), Lean Manufacturing, 5S, SMED, Metalworking Industry

1. Introduction
The Peruvian metalworking industry is a key support for mining and construction, but it has recurring problems of variability, lack of standardization, and high operator dependency, factors that affect delivery compliance (Mundaca-López et al., 2023; Ramos et al., 2022). The company studied, which repairs hydraulic cylinders, demonstrates these limitations with an OTD of 43.15%, generating overtime, rework, and penalties equivalent to 3.86% of its turnover. The diagnosis identified three main causes: operational disorder, lack of a standardized setup, and unstable cooling control in chrome plating. These findings coincide with those reported in the literature, where disorder increases unproductive time (Manzanares-Cañizares et al., 2022), the lack of standardization prolongs setups (Chávez & Molina, 2022), and the absence of autonomous control in critical processes increases rework (Sánchez et al., 2021). Although Lean tools such as 5S, SMED, and Jidoka have shown significant improvements in productivity and process stability (Huertas-Reyes et al., 2022; Yalico-Luciano et al., 2023), their integrated application in cylinder repair operations has been poorly documented, revealing a technical gap compared to the industry standard of OTD close to 75%. In response, this study proposes a management model based on 5S, SMED, and Jidoka to reduce variability and improve flow reliability. Its validation using Arena and DWSIM shows that OTD increases from 43.2% to 83%, demonstrating the effectiveness of the integrated approach.

1.1 Objectives

Increase the performance of the On-Time Delivery (OTD) indicator in a metalworking company dedicated to the repair and manufacture of hydraulic cylinders through the integrated implementation of 5S, SMED, and Jidoka, with the aim of reducing operational variability and improving delivery reliability.

To achieve this goal, the study proposes the following specific objectives:

- Apply the 5S methodology in operational areas to improve order, standardization, and tool availability, reducing unproductive time associated with searching and disorganization.
- Standardize and optimize the setup process using SMED, separating internal and external tasks to reduce preparation times and increase the availability of critical equipment.
- Design and implement a Jidoka system that automates water level control in the chrome plating cooling process using a sensor with an alarm, reducing thermal variability, failures, and reprocessing.

2. Literature Review

Specialized literature on metalworking production points out that operational variability, lack of standardization, and downtime directly affect on-time delivery (OTD) performance. In this context, various studies highlight the positive impact of Lean tools such as 5S, SMED, and Jidoka, widely applied in machining, maintenance, and repair workshops to stabilize processes and improve delivery reliability (Ávalos-Ortecho et al., 2023; Delgado et al., 2022; Sánchez & Torres, 2022).

2.1. 5S and Workspace Organization

The 5S methodology is one of the most effective tools for reducing losses associated with clutter, searching for tools, and unnecessary movements. Studies in metalworking SMEs report reductions of between 30% and 55% in unproductive time after its implementation, as well as improvements in visual standardization and operational discipline (Carranza-Inga et al., 2021; Murrieta et al., 2024; Wong et al., 2020). Likewise, 5S contributes to reducing the variability derived from manual intervention by ensuring immediate availability of resources (Flórez-Cáceres et al., 2024).

2.2. SMED and Setup Time Reduction

The SMED method allows activities to be reorganized and internal tasks to be converted into external ones, reducing setup times by between 40% and 70% in turning, milling, and grinding processes (Trojanowska et al., 2020; Domínguez et al., 2020; Silva & Delgado, 2021). Its implementation improves equipment availability and reduces flow variability, generating direct impacts on delivery time compliance (Huertas-Reyes et al., 2022; Lora-Soto et al., 2021).

2.3. Jidoka and Automatic Control of Critical Processes

Jidoka incorporates automatic deviation detection mechanisms that allow the process to be stopped and prevent defects from spreading. Recent literature shows that automation systems based on sensors, real-time control, and artificial intelligence have significantly reduced variability and rework in sensitive operations such as heat treatments, surface finishing processes, and high-precision assemblies (Hütten et al., 2024; Hussain et al., 2022; Li et al., 2023). These solutions integrate continuous monitoring, autonomous control, and automatic activation in the event of abnormal conditions, which directly contributes to improving operational stability and OTD compliance (Alrabghi & Tiwari, 2021; Singh & Kumar, 2020).

In order to summarize the findings in the literature, three operational typologies have been identified in which these Lean tools have proven to be most effective. The following Table 1 summarizes the most common patterns, their causes, and the associated tools, integrating the evidence reviewed:

Table 1. Types identified in the literature

Tipology	Main causes	Effective tools
Low OTD	Disorder, extensive setups, unstable processes	5S, SMED, Jidoka
High rework rates	Lack of process control, late detection, operational variability	Jidoka, 5S, SMED
Low Productivity	Unnecessary motions, non-value-added tasks, repeated adjustments	SMED, 5S, Jidoka

This body of evidence confirms that the integration of 5S, SMED, and Jidoka constitutes a consistent and widely supported approach to improving OTD in metalworking companies, especially in highly variable processes such as hydraulic cylinder repair.

3. Methods

The proposed model consists of three interventions (5S, SMED, and Jidoka) designed to correct deficiencies identified in the hydraulic cylinder repair process. Unlike the literature review, this section does not describe the theoretical foundations of each tool, but rather how they were specifically applied within the process studied and how they act as transformation mechanisms to improve the On-Time Delivery (OTD) indicator. The model inputs correspond to three operational limitations identified in the diagnosis:

1. Disorder and lack of standardization in the work area,
2. Variability in setup execution, and
3. thermal instability during the chrome plating process.

The transformation mechanisms are the specific interventions applied through 5S, SMED, and a Jidoka pilot modeled in DWSIM. The outputs are reflected in improvements in operational order, reduced setup times, and fewer reworks due to thermal defects. Figure 1 presents the conceptual model that integrates these relationships.

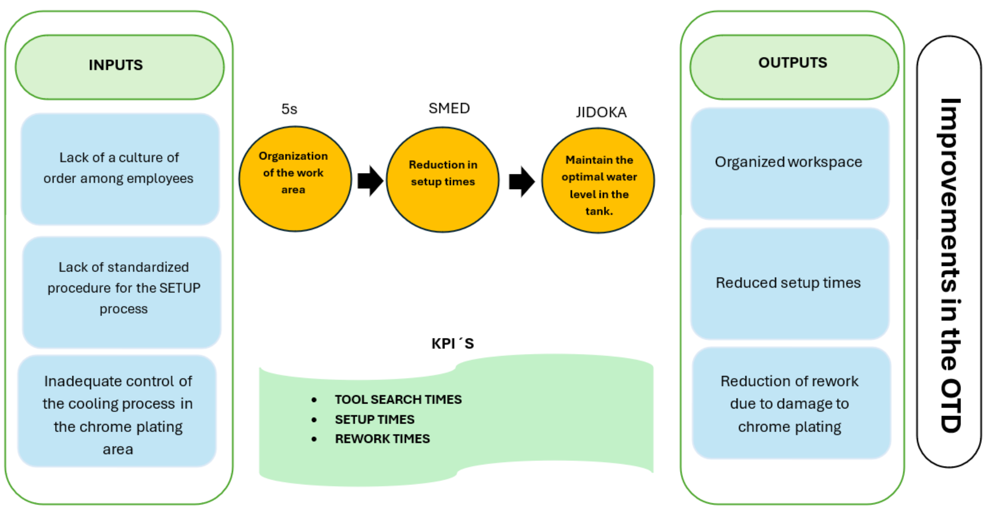

Figure 1. Conceptual model

Table 2 summarizes the three components of the improvement mode.

Table 2. Components of the improvement model

Component	Purpose	Key Actions	Expected / Achieved Outcomes
1. 5S – Operational Organization	Reduce workplace disorder and tool-search time.	- Reorganize the work area. - Assign fixed locations for tools and materials. - Implement visual signaling and labeling. - Remove unnecessary items that interrupt workflow.	- Lower operator-induced variability. - Stable conditions to support setup standardization.
2. SMED – Setup Standardization	Address the lack of a formal setup method.	- Classify internal and external tasks. - Reorganize sequences and eliminate unnecessary motions. - Develop standardized procedures, checklists, and preset templates. - Provide visual guides for operators.	- Reduction of setup time. - Decreased dependence on operator judgment - More stable and predictable workflow.
3.Jidoka Autonomation Pilot Using DWSIM	Stabilize the chrome-plating process and reduce rework caused by thermal fluctuations.	- Model the cooling system in DWSIM. - Define an autonomous mechanism based on tank-level and temperature deviations. - Install a level sensor that activates water flow automatically. - Ensure continuous cooling and prevent overheating.	- Reduced thermal instability. - Prevention of unplanned process interruptions. - Significant reduction of rework in chrome plating.
Integrated Validation	Evaluate the combined effect of the three components.	- Arena simulation to assess workflow improvements from 5S and SMED. - DWSIM simulation to evaluate the autonomous cooling system under Jidoka.	- OTD increased from 43.2% to 83%. - Demonstrated technical robustness and operational effectiveness.

4. Data Collection

Information was collected over a one-year period from the company, showing all the work carried out by the company with the aim of characterizing the actual demand and operational load on the system. Historical records showed a high degree of heterogeneity in the equipment involved, with excavators (196 units, 23%) followed by front loaders (97 units, 11%), crawler tractors (87 units, 10%), mining trucks (84 units, 10%), drills (82 units, 10%), and backhoes (59 units, 7%), among others. Since excavators were the type of equipment that received the most attention and accounted for the largest share of the annual volume of work, the study was segmented exclusively into this group. This delimitation made it possible to reduce operational variability and ensure consistency in the construction of the simulation model. Additionally, 693 direct time measurements were taken in the main operations of the metalworking process: chrome plating (168), burnishing (107), welding (106), milling (105), hydraulics (104), and turning (103). These measurements made it possible to quantify the critical factors associated with the low level of On-Time Delivery (OTD), mainly setup times, unproductive times, and rework frequency. The consolidated database was used to rigorously parameterize the as-is and to-be scenarios of the simulation model, on which the impact of the integrated implementation of Lean tools (5S, SMED, and Jidoka) was evaluated.

5. Results and Discussion

5.1 Proposed Improvements

Implementation of 5S: The application of the 5S methodology restored order in the work area through classification, organization, cleaning, standardization, and discipline. Unnecessary items were removed, tools were coded and properly identified, visual signaling was introduced, and operational zones were reorganized according to ergonomic and workflow criteria.

Direct results:

- 67% reduction in tool-searching time
- Fewer interruptions in the work sequence
- Lower dependency on operator criteria
- Safer and cleaner working conditions

Implementation of SMED: SMED was applied to the machine setup process. Although each piece of equipment exhibited different baseline preparation times, the global analysis demonstrated an average reduction of **33%** in setup time. The intervention resulted in:

- A clear separation between internal and external activities
- Elimination of unnecessary movements
- Improved adjustment sequences
- Greater homogeneity in operator performance

SMED played a decisive role in stabilizing operations and reducing process variability.

Implementation of Jidoka

An automatic system was developed to control the water level in the chroming tank. This system uses a sensor that activates refilling when the level drops, ensuring that the temperature of the process remains within the appropriate operating range.

Observed benefits:

- Elimination of thermal reprocessing
- Reduction of human errors
- Lower defect rate in the chroming stage
- Stable flow in one of the most critical stages of the process

5.2 Numerical and Graphical Results

The application of Lean 5S, SMED, and Jidoka tools generated significant quantitative improvements in the operational performance of the hydraulic cylinder repair and manufacturing process. These improvements are mainly reflected in the reduction of downtime, the standardization of preparation activities, and the elimination of critical rework associated with the chrome plating process.

In terms of area efficiency, the time spent searching for tools was reduced from 15.2 minutes per day to 5 minutes per day, which is equivalent to a 67% improvement, thanks to the implementation of 5S and the visual organization of the area. Furthermore, the standardization of the process through SMED made it possible to standardize internal and external setup activities, eliminating variations between operators and reducing the operational burden associated with repetitive adjustments.

Likewise, the implementation of the Jidoka system made it possible to drastically reduce rework due to failures in the control of the chrome plating water level. The error rate went from 11.29 hours to 0 hours, representing a 100% reduction, ensuring the thermal stability of the process and the elimination of recurring defects.

Finally, these improvements had a direct impact on the project's main indicator: On-Time Delivery (OTD). The initial compliance level was 43%, while in the improved scenario, with the process stabilized and no reprocessing, an OTD of 83% was achieved, meeting the objectives set (Table 3).

Table 3. Summary of results

Indicator	**AS IS**	**TO BE**
Tool search time	15.2 min/day	5 min/day
Error rework rate (chrome plating)	20%	0
Variability in setup	0	-33%
OTD	43%	83%

SMED

The application of the SMED methodology produced a substantial reduction in the setup times of the machining processes. Before the improvement, the average changeover duration across the evaluated equipment was approximately 19 minutes, whereas after the implementation it decreased to 12 minutes, which represents a 36.8% reduction. This improvement was the result of reorganizing the workflow, redefining the sequence of activities, and ensuring that several tasks could be performed without stopping the machine.

During the diagnostic stage, a total of 19 internal activities and no external activities were identified, revealing a high dependence on tasks performed with the machine stopped. After reorganizing the setup procedure under the SMED framework, the distribution changed to 8 internal tasks and 11 external tasks, shifting a significant portion of the workload outside machine downtime. The introduction of tool-kits, standardized layouts, and visual setup instructions supported the execution of the new procedure and reduced operator variability. Time measurements performed during the pilot phase confirmed the consistency of the results and validated the reduction in changeover time (Table 4).

Table 4. Comparison of setup times before and after SMED implementation.

Stage	**Min Time**	**Max Time**	**Average Time**	**Improvement (avg)**
Initial setup time	17 min	23 min	19 min	—
Final setup time (SMED)	10 min	14 min	12 min	7 min (≈36.8%)

5S

The implementation of the 5S program generated progressive improvements in workplace organization, visibility, and cleanliness within the machining and hydraulic areas. The results of the final audit indicate significant advances in the first stages of the methodology. Seiri reached a compliance level of 60%, reflecting a consistent removal of unnecessary items and a more efficient use of space. Seiton and Seiso obtained scores of 48%, showing improvements in tool localization, labeling, and cleaning routines, although still requiring reinforcement to reach full stability.

Seiketsu achieved a lower result of 28%, evidencing that visual standards and standardized layouts are still in an early consolidation phase. Finally, Shitsuke registered 0%, confirming that discipline and long-term adherence to the system remain the primary challenge for the organization. These outcomes are aligned with the monitoring conducted during the 39 days of audits and 33 days of follow-up, which documented visible improvements but also highlighted the need for sustained reinforcement to ensure continuity of the program.

The improved scenario shows a strong increase across all 5S pillars: Seiri reaches 92%, Seiton 90%, Seiso 87%, Seiketsu 82%, and Shitsuke 82%, reflecting a more standardized, visually organized, and disciplined workspace compared to the initial condition (Figure 2).

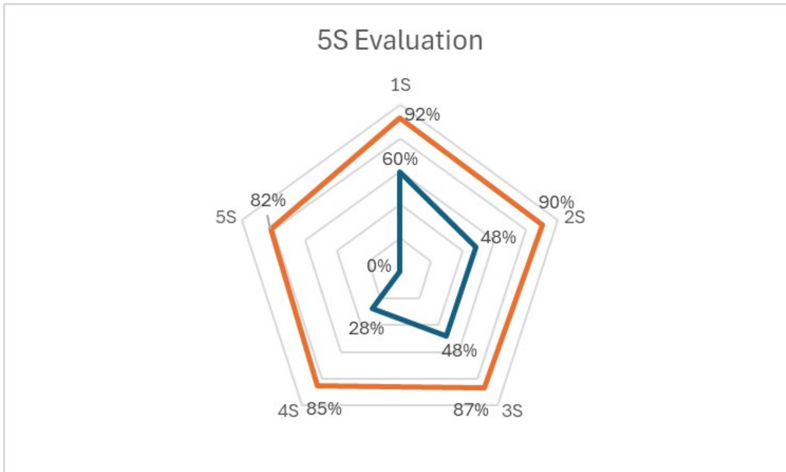

Figure 2. 5S Evaluation

Jidoka

Before the implementation of the Jidoka-based autonomous filling system, the chrome plating process experienced recurring thermal deviations due to irregular water replenishment in the cooling tank. These fluctuations often exceeded 53°C, causing adhesion failures, surface defects, and instability in the chrome layer. As a result, the process accumulated a rework rate of 20% of total production, increasing delivery times and affecting reliability in one of the most critical stages of the plant.

The integration of the automatic level-control system—simulated in DWSIM and illustrated in Figure 3—made it possible to detect when the water level dropped to 0.5 m using a sensor, autonomously activating the filling up to 2.5 m in a 3 m-high tank. This mechanism eliminated the previous manual dependency and ensured stable cooling throughout the chromium-plating cycle, maintaining constant hydraulic conditions and preventing the system from operating with insufficient water volumes. Additionally, through VALVE-2, the company has implemented a continuous water-extraction system that feeds the cooling circuit of the chrome bath, ensuring constant heat removal and contributing to the stabilization of the bath temperature.

Following implementation, thermal instability was completely eliminated and the rework rate was reduced from 20% to 0%, reflecting a total improvement in process reliability, defect prevention, and operational stability.

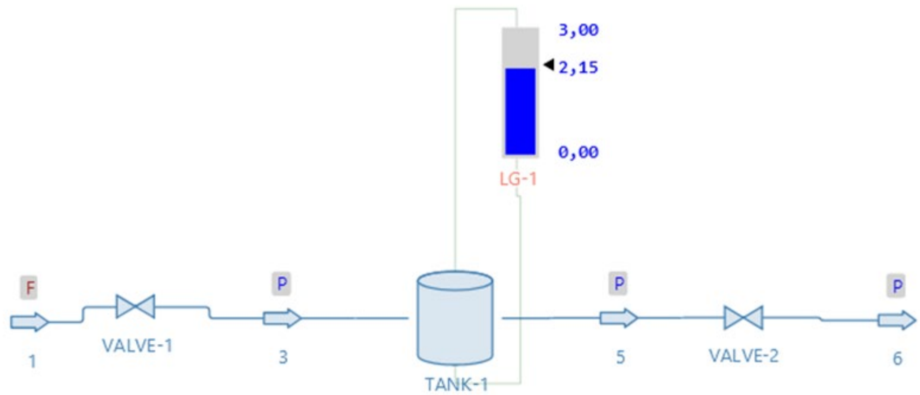

Figure 3. Piping and Instrumentation Diagram of the Jidoka Water-Level Control System

To validate the performance of the proposed Jidoka mechanism, Figure 4 presents the dynamic simulation results obtained in DWSIM. These results show that the variable T1—representing the liquid level inside the tank—never approached zero at any point during the analysis, even under high thermal-load conditions. This behavior confirms that the automatic replenishment system consistently maintains the required water flow for cooling, preventing any critical depletion of the tank. Consequently, the likelihood of rework caused by insufficient cooling water becomes practically negligible, ensuring thermal stability and improving reliability in the chroming stage.

Time (s)	T1 (m)
0	0,0898
300	0,1794
600	0,2689
900	0,3584
1200	0,4480
1500	0,5375
1800	0,6270
2100	0,7166
2400	0,8061
2700	0,8956
3000	0,9852
3300	1,0747
3600	1,1642
3900	1,2538
4200	1,3433
4500	1,4328
4800	1,5224
5100	1,6119
5400	1,7014
5700	1,7910
6000	1,8805
6300	1,9700
6600	2,0596

Figure 4. Simulation Results in DWSIM of the Jidoka

5.3 Validation

The validation of the improved production model was performed through simulation using Arena software, with the objective of quantitatively assessing the operational impact of the Lean tools implemented—5S, SMED, and Jidoka on the repair and manufacturing process of hydraulic cylinders. This stage made it possible to compare the system's behavior before and after the improvements, ensuring that the proposed changes effectively reduced variability and enhanced delivery performance.

In the initial scenario, the AS-IS model accurately reproduced the real operating conditions of the company. The simulation revealed high variability in processing times, recurrent rework caused by thermal instability in the chroming stage, and delays generated by tool-searching activities and prolonged setups. Under these conditions, the main indicator, On-Time Delivery (OTD), yielded an average value of 0.372, with a 95% confidence interval [0.332, 0.411]. This relatively wide interval reflects the instability and limited predictability of the original operational flow, confirming that the model successfully captures the real deficiencies of the process.

The TO-BE scenario was then simulated incorporating the proposed Lean interventions. The 5S methodology significantly reduced interruptions caused by workplace disorder and lack of materials; SMED standardized the setup times in the main machining stations, decreasing operator-dependent variability; and Jidoka eliminated the rework associated with manual control of the cooling-water level, stabilizing the thermal behavior of the chroming process and ensuring coating quality. These improvements were programmed directly into the TO-BE model while keeping the same simulation conditions to allow a fair comparison with the original system.

The results of the improved scenario showed a substantial increase in system responsiveness. The average OTD rose to 0.835, with a 95% confidence interval [0.822, 0.847]. Unlike the initial model, this interval is considerably narrower, indicating a more stable process with lower variability and a higher probability of consistently meeting delivery commitments. The contrast between both intervals demonstrates not only a significant increase in delivery performance but also a homogenization of operational behavior.

Beyond the improvement in OTD, the simulation also showed a reduction in bottlenecks, decreased variability in machining times, and the complete elimination of chroming-related rework. These results align with the expected effects of applying Lean tools, thereby technically validating the proposed model.

Overall, the Arena-based validation confirms that the integration of 5S, SMED, and Jidoka generates measurable, consistent, and statistically reliable improvements. The increase in OTD—from an initial, unstable interval to a high and narrow confidence range—demonstrates that the proposed solution effectively addresses the identified root causes, stabilizes the workflow, and significantly increases process predictability. Therefore, the improved model is technically sound and viable for future implementation within the company (Figure 5).

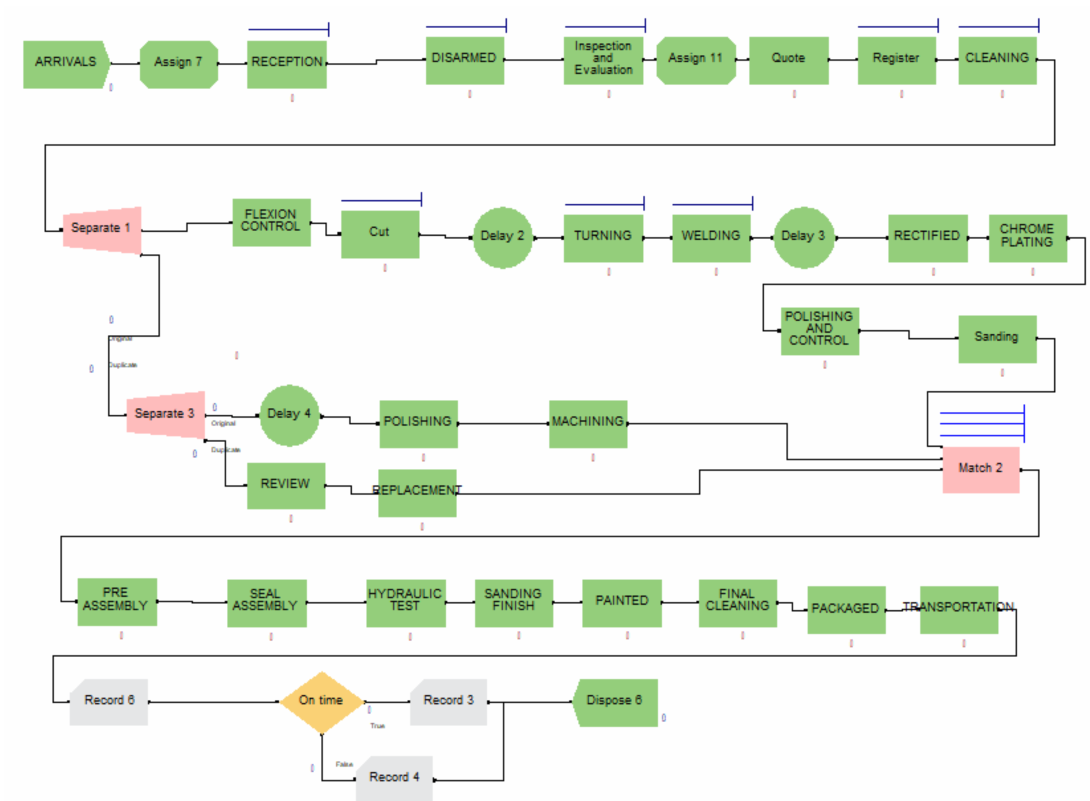

Figure 5. Arena simulator

6. Conclusion

The integrated implementation of 5S, SMED, and Jidoka improved work organization, standardized setups, and stabilized the cooling system in the chrome plating process, reducing downtime and rework. By incorporating these improvements into the simulation model, the On-Time Delivery (OTD) indicator increased from 43.2% to 83%, demonstrating significant progress in operational reliability and efficiency. However, the results should be interpreted with caution, as validation was performed exclusively through simulations, which do not fully reproduce real conditions, such as variations in resource availability or human factors. In addition, the study focused only on three Lean tools, without considering other organizational elements that influence the sustainability of the improvements. It is recommended that future research evaluate the application of the model in real environments and analyze its behavior under different operational scenarios.

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Biographies

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