

Lean Line Concept Checklist for Industrial Workstations

R. Christu Paul¹, Vishhal Sreenevasan Vasanthi²

^{1,2}*Department of Automobile Engineering, Hindustan Institute of Technology and Science,
Chennai 603 103*

Abstract—In modern manufacturing environments, achieving high productivity, quality consistency, and operational efficiency requires the systematic integration of lean principles. This study presents the development and implementation of a Lean Line Concept (LLC) Compliance Checklist for industrial workstations, aimed at standardizing processes, improving ergonomics, and enhancing overall line performance. The proposed framework incorporates key parameters such as workplace design, ergonomics, poka-yoke mechanisms, material flow, safety, and changeover flexibility to ensure a holistic evaluation of manufacturing stations. Implementation of the LLC checklist enables the identification of process gaps, inconsistencies, and inefficiencies across multiple stations, facilitating targeted improvements and continuous monitoring. The approach supports lean manufacturing objectives by enhancing line balancing, reducing cycle time, and improving overall equipment effectiveness (OEE). Additionally, it provides a scalable and replicable model that can be adapted across different manufacturing domains. The results demonstrate that the adoption of a structured LLC compliance framework significantly improves operational transparency, standardization, and productivity, while ensuring adherence to industrial best practices. This checklist highlights the importance of integrating lean methodologies with practical evaluation tools to drive sustainable manufacturing excellence for production systems.

Index Terms—Lean Manufacturing, Industrial Workstations, Process Standardization, Ergonomics

I. INTRODUCTION

In today's competitive manufacturing landscape, organizations are increasingly adopting lean methodologies to eliminate waste and enhance operational efficiency. Despite the widespread implementation of lean tools such as 5S, Value Stream Mapping (VSM), and Kaizen, many industries continue to face challenges in achieving consistent

workstation performance due to the absence of standardized evaluation frameworks. This lack of uniform assessment methods often results in variability in process execution, reduced productivity, and difficulty in monitoring continuous improvement initiatives at the shop-floor level.

Existing lean assessment approaches are predominantly fragmented and qualitative in nature, focusing on isolated aspects of production systems rather than providing an integrated evaluation mechanism. Furthermore, these tools often lack a structured scoring methodology, making it difficult to quantitatively measure, compare, and benchmark workstation performance across different production environments. In addition, limited attention has been given to the simultaneous consideration of multiple critical domains such as ergonomics, safety, material flow, and quality within a unified evaluation framework, thereby highlighting a significant research gap in current lean implementation practices.

To address these limitations, this study proposes a structured Lean Line Concept (LLC) Compliance Checklist designed to ensure the uniform application of lean principles across industrial workstations. The novelty of the proposed approach lies in its ability to integrate multi-domain evaluation with a quantitative scoring system, enabling a systematic and measurable assessment of workstation performance. Unlike conventional lean audit tools, the LLC checklist facilitates real-time evaluation, effective gap identification, and data-driven decision-making, thereby supporting continuous improvement in manufacturing operations.

The contributions of this study are threefold. First, it presents a standardized LLC checklist framework tailored for industrial workstations. Second, it introduces a quantitative compliance evaluation model that enables objective performance measurement. Third, it integrates multiple lean domains into a

comprehensive assessment tool while providing a practical implementation methodology validated through an industrial case study.

II. LITERATURE REVIEW

Recent studies published between 2020 and 2025 indicate a growing emphasis on the adoption of lean manufacturing tools to enhance productivity, reduce waste, and improve operational efficiency. Techniques such as 5S audits, Value Stream Mapping (VSM), lean audit sheets, and Six Sigma methodologies are widely implemented across industries. The 5S audit primarily focuses on workplace organization and cleanliness, thereby improving visual management and discipline at the shop-floor level. Similarly, Value Stream Mapping is extensively used for visualizing material and information flow within production systems, enabling the identification of bottlenecks and non-value-added activities. Lean audit sheets provide a general framework for evaluating lean implementation, while Six Sigma tools emphasize quality improvement through defect reduction and process optimization.

Despite their advantages, these methods exhibit several limitations when applied to workstation-level evaluation. The 5S audit lacks performance-oriented metrics, making it insufficient for measuring operational efficiency. VSM, although effective in flow analysis, does not provide detailed insights at the individual workstation level. Lean audit sheets are often generalized and lack standardized scoring mechanisms, leading to subjective assessments. Furthermore, Six Sigma tools, while highly effective for quality improvement, involve complex statistical techniques that may not be practical for routine shop-floor evaluation. A critical analysis of these approaches reveals several gaps in existing lean assessment methodologies. There is a lack of an integrated checklist that comprehensively covers all essential lean domains, including ergonomics, safety, material flow, and quality. Additionally, most tools do not support real-time applicability and continuous monitoring in dynamic manufacturing environments. The absence of a quantitative benchmarking system further limits the ability to measure and compare performance across different workstations. Moreover, insufficient attention has been given to ergonomic and

safety considerations, which are crucial for sustainable productivity and operator well-being.

These limitations highlight the need for a structured and comprehensive evaluation framework. Consequently, this study proposes a Lean Line Concept (LLC)-based checklist system that addresses these gaps by integrating multiple lean domains with a standardized and quantitative assessment approach.

III. METHODOLOGY

The LLC Compliance Checklist is developed based on core lean manufacturing principles, an extensive review of recent literature, and practical insights derived from industrial observations. The checklist development approach integrates established lean tools and best practices with real-time shop-floor requirements to ensure both theoretical relevance and practical applicability. The framework categorizes workstation evaluation into multiple domains, enabling a comprehensive and holistic assessment of operational performance. Each domain is defined with specific criteria to systematically evaluate various aspects such as ergonomics, material flow, quality, safety, and process efficiency.

To ensure objective and consistent evaluation, a structured scoring system is incorporated into the checklist. A Likert scale-based approach is adopted, where each parameter is rated on a scale ranging from 0 to 4, representing levels from “not implemented” to “fully implemented.” This scoring mechanism enables quantitative assessment of workstation compliance and reduces subjectivity in evaluation. The use of a standardized scale facilitates comparison across different workstations and supports performance benchmarking.

Furthermore, a mathematical compliance model is introduced to quantify the overall performance of a workstation. The LLC compliance score is calculated as the ratio of the sum of obtained scores to the maximum possible score, expressed as a percentage. This provides a clear and measurable indicator of the degree of lean implementation at each workstation, enabling easier identification of performance gaps and prioritization of improvement actions.

The evaluation procedure follows a systematic step-by-step workflow to ensure consistency and repeatability. Initially, the workstation is selected and assessed using the predefined checklist criteria.

Observations are recorded, and individual scores are assigned for each parameter. The overall compliance score is then calculated using the proposed model. Based on the results, gaps and inefficiencies are identified, followed by the recommendation and implementation of corrective actions. A re-evaluation is conducted after improvements to measure the effectiveness of the interventions. This structured workflow enables continuous monitoring and supports data-driven decision-making for sustained operational improvement.

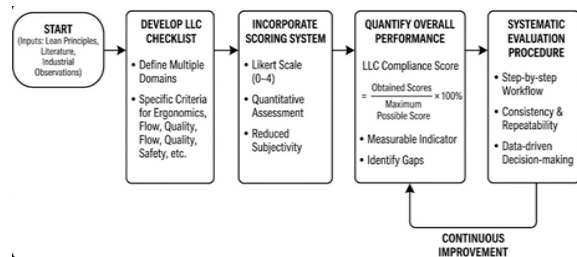


Fig. 1. Methodology Block Diagram

IV. LLC COMPLIANCE DOMAINS

The checklist framework is structured across key domains, including general design for layout optimization and effective space utilization, ergonomics to ensure operator comfort and reduce fatigue, and poka-yoke and quality to enable error-proofing and defect prevention. Each domain is defined with detailed evaluation criteria and supported by specific indicators to ensure a comprehensive and systematic assessment. For instance, the general design domain evaluates criteria such as workstation layout efficiency, accessibility, and space utilization, with indicators including optimal placement of tools and minimal operator movement. The ergonomics domain focuses on operator posture, reach distance, and fatigue reduction, with indicators such as adjustable work height and minimized repetitive strain.

Similarly, the poka-yoke and quality domain assesses the presence of error-proofing mechanisms and quality control measures, with indicators such as mistake-proof devices and in-process inspection systems. The material supply and storage domain evaluates inventory organization, availability, and handling efficiency, including indicators such as FIFO implementation and clearly labeled storage locations.

The changeover and flexibility domain emphasizes setup time reduction and adaptability, with indicators such as quick changeover techniques and standardized procedures.

The safety domain addresses hazard identification, risk mitigation, and compliance with safety standards, including indicators such as proper use of personal protective equipment and emergency readiness. The material flow domain ensures smooth and uninterrupted operations through criteria such as continuous flow and minimal bottlenecks, supported by indicators like streamlined movement of materials and reduced waiting time. Controls and visual management focus on clear communication and guidance through indicators such as visual instructions, signages, and Andon systems. The maintenance domain evaluates equipment reliability and preventive practices, including indicators such as scheduled maintenance and minimal downtime.

Checklist Categories

SL NO.	LLC DOMAIN
1.	General Design
2.	Ergonomics
3.	Poka-Yoke and Quality
4.	Material Supply and Storage
5.	Changeover and Flexibility
6.	Safety
7.	Material Flow
8.	Controls and Visual Management
9.	Maintenance
10.	Overall Assessment

Finally, an overall assessment integrates the performance across all domains to provide a comprehensive evaluation of workstation efficiency and compliance. This structured expansion of the LLC framework ensures that each domain is not only clearly defined but also measurable through practical indicators, thereby enabling accurate assessment, effective gap identification, and continuous improvement.

LLC Framework

Sl. No.	LLC Domain	Detailed Criteria
1.	General Design	Layout efficiency, space utilization, accessibility
2.	Ergonomics	Operator posture, reach distance, fatigue reduction
3.	Poka-Yoke & Quality	Error-proofing, defect prevention, inspection systems

4.	Material Supply & Storage	Inventory organization, availability, handling efficiency
5.	Changeover & Flexibility	Setup time reduction, adaptability, standardization
6.	Safety	Hazard identification, risk control, compliance
7.	Material Flow	Continuous flow, bottleneck reduction, smooth movement
8.	Controls & Visual Management	Visual instructions, communication, monitoring systems
9.	Maintenance	Preventive maintenance, equipment reliability, downtime reduction
10.	Overall Assessment	Integrated performance evaluation across domains

V. CASE STUDY / IMPLEMENTATION

The proposed LLC Compliance Checklist was implemented in an automotive manufacturing environment to evaluate its practical applicability and effectiveness. The study was conducted at an assembly line workstation where manual and semi-automated operations are performed. The selected workstation involved component assembly tasks requiring coordinated material handling, operator interaction, and quality checks, making it suitable for evaluating multiple lean domains simultaneously.

A total of five workstations within the assembly line were selected for evaluation to ensure a comprehensive assessment across different operational stages. These stations included material preparation, sub-assembly, main assembly, inspection, and finishing processes. Each workstation was analysed individually using the LLC checklist to identify domain-specific inefficiencies and overall performance gaps.

The data collection procedure involved a combination of direct observation, time study analysis, and operator feedback. Observations were recorded for each checklist parameter, and performance scores were assigned based on the predefined Likert scale. Cycle time measurements were taken using a stopwatch method, while qualitative inputs were gathered from operators to understand ergonomic issues and operational challenges. All collected data were systematically documented to ensure accuracy and consistency in evaluation.

SUB ASSEMBLY STATION: 2
ASSET. No. 3703035360

Check List - LLC Compliance.		
Section	Checklist Item	Status
General Design	Workplace design follows walk-and-stand criteria	✓
General Design	Layout is simple and clutter-free	✓
General Design	Workplace width is <= 600 mm	✓
General Design	Maximum station height is <= 1600 mm	✓
General Design	Visual appearance is standardized across the line	✓
Ergonomics	Working height matches Blud Card N62C standard	✓
Ergonomics	Height defined from working/standing height, not tabletop	✓
Ergonomics	Operator can work without bending, stretching, or twisting	✓
Ergonomics	Good visibility of parts and operations	✓
Ergonomics	Safety light curtains (if used) are inclined about 10 degrees backward for better visibility	NA
Poka-Yoke & Quality	Poka-Yoke implemented (forming nests / mechanical solution)	✓
Poka-Yoke & Quality	Part orientation is error-proof	✓
Poka-Yoke & Quality	Finished parts automatically ejected (Kanedeshi)	✓
Poka-Yoke & Quality	Ejection to nest next (<= 150 mm reach) / outside safety curtain / defined safe area	✓
Poka-Yoke & Quality	NOK parts are not handled at the station	✓
Poka-Yoke & Quality	NOK part chutes lead to defect analysis table outside the line	✓
Material Supply & Storage	Material supplied only from rear side	✓
Material Supply & Storage	Loading height is comfortable for operator	✓
Material Supply & Storage	Storage bins/chutes placed near loading future (reach <= 150 mm)	✓
Material Supply & Storage	Storage bin capacity defined as per working cycle	✓
Material Supply & Storage	Closing doors/Covers used only if process demands	✓
Changeover & Flexibility	Changeover can be done by operator	✓
Changeover & Flexibility	No tools required for changeover (where possible)	✓
Changeover & Flexibility	Changeover time within line cycle target	✓
Changeover & Flexibility	Changeover includes jig/tooling/process components/SIW/WI	✓
Changeover & Flexibility	Work Station on wheels (if technically feasible)	✓
Changeover & Flexibility	Layout supports quick change between product variants	✓
Safety	Safety light curtains installed where required	NA
Safety	Safety devices do not obstruct visibility	✓
Safety	Operator movement is safe and unobstructed	✓
Safety	No sharp edges or unsafe protrusions	✓
Safety	Emergency access is clear	✓
Material Flow	Material flow follows standardized plant direction (e.g., clockwise)	✓
Material Flow	No backflow or cross movement	✓
Material Flow	Inbound and outbound paths clearly defined	✓
Controls & Visual Management	Control elements located at same position across all stations	✓
Controls & Visual Management	Labels, markings, and visual cues are standardized	✓
Controls & Visual Management	Instructions clearly visible at point of use	✓
Maintenance & TPM	Workplace design allows easy cleaning	✓
Maintenance & TPM	Components are easy to access for maintenance	✓
Maintenance & TPM	Damaged components can be replaced quickly	✓
Maintenance & TPM	No hidden or hard-to-reach areas	✓
Overall Assessment	Workplace meets Lean Line Concept	✓
Overall Assessment	No ergonomic, safety, or quality risks observed	✓

Fig.2. Lean Line Concept – Checklist for Sub Assembly Station

Before the implementation of the LLC framework, several inefficiencies were observed, including improper workstation layout, excessive operator movement, lack of standardized work procedures, and inadequate material organization. These issues resulted in higher cycle time, increased operator fatigue, and inconsistent quality output. Based on the checklist evaluation, targeted corrective actions were proposed, such as layout redesign, implementation of visual management tools, ergonomic improvements, and standardization of work procedures.

After the implementation of these improvements, a re-evaluation was conducted using the same checklist framework. The results indicated significant enhancements in workstation performance, including reduced cycle time, improved material flow, better ergonomic conditions, and increased operator efficiency. The before-and-after comparison clearly demonstrates the effectiveness of the LLC Compliance Checklist as a practical tool for identifying inefficiencies and driving continuous improvement in industrial workstations.

VI. RESULTS AND DISCUSSION

The implementation of the LLC Compliance Checklist across industrial workstations led to significant improvements in overall operational performance. The structured evaluation approach enabled the systematic identification of bottlenecks, reduction of non-value-added activities, and enhancement of process consistency. By adopting a domain-wise assessment methodology, the framework facilitated targeted improvements across multiple aspects of the workstation, resulting in measurable performance gains.

Quantitative analysis of key performance indicators demonstrated substantial improvements after the implementation of the LLC framework. The average cycle time was reduced from 120 seconds to 95 seconds, indicating a significant enhancement in operational efficiency. Similarly, Overall Equipment Effectiveness (OEE) improved from 65% to 82%, reflecting better utilization of resources and reduced downtime. Defect rates were reduced from 8% to 3%, highlighting the effectiveness of error-proofing and quality control measures. Additionally, operator efficiency increased from 70% to 88%, demonstrating improved ergonomics and workflow optimization.

A comparative analysis of pre- and post-implementation performance is presented in Table II, which clearly illustrates the improvements across key metrics. The table provides a concise representation of performance enhancement achieved through the LLC checklist, enabling easier benchmarking and validation of results. Furthermore, graphical representations such as bar charts and trend plots can be used to visually depict the improvements in cycle time, OEE, defect rate, and operator efficiency, thereby enhancing the interpretability of the results.

Domain-wise performance analysis revealed that the most significant improvements were observed in ergonomics, material flow, and quality domains. Ergonomic enhancements reduced operator fatigue and improved productivity, while improved material flow minimized delays and eliminated bottlenecks. The implementation of poka-yoke mechanisms and standardized procedures contributed to a substantial reduction in defects. Safety and visual management domains also showed notable improvements, ensuring better compliance and operational transparency.

Overall, the results demonstrate that the LLC Compliance Checklist not only provides a structured and measurable evaluation framework but also serves as an effective tool for driving continuous improvement. The integration of quantitative metrics, comparative analysis, and domain-wise insights reinforces the practical applicability and effectiveness of the proposed methodology in enhancing industrial workstation performance.

SUB ASSEMBLY STATION

LLC COMPLIANCE CHECKLIST

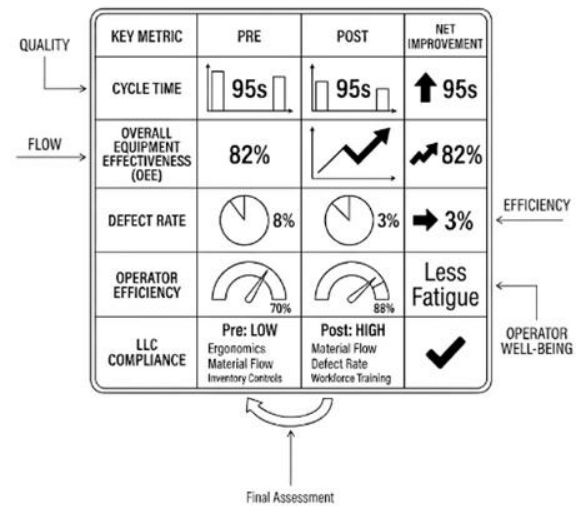


Fig. 3. Impact Analysis of LLC Implementation on Sub – Assembly Operations

VII. CONCLUSION

In conclusion, the implementation of the Lean Line Concept (LLC) Compliance Checklist demonstrates a structured and effective approach to enhancing industrial workstation performance through the integration of lean manufacturing principles. By systematically evaluating critical domains such as ergonomics, material flow, quality assurance, and safety, the framework enables the identification of inefficiencies and supports targeted, data-driven improvements. The observed outcomes including reduced cycle time, improved line balancing, enhanced operator efficiency, and better-quality adherence highlight the practical impact of the checklist in driving operational excellence.

Furthermore, the framework promotes standardization, transparency, and continuous improvement, making it a scalable and adaptable tool for diverse manufacturing environments. Overall, the LLC Compliance Checklist serves as a valuable mechanism for achieving sustainable productivity, reliability, and competitiveness in modern production systems.

REFERENCES

- [1] Colim et al., "Lean manufacturing and ergonomics integration: Defining productivity and wellbeing indicators in a human-robot workstation," *Sustainability*, vol. 13, no. 4, p. 1931, 2021.
- [2] S. Brunner, M. Siebenbürger, K. Kühnel, and K. Bengler, "Promoting human-centered manufacturing through lean ergonomics: A structural equation model," *Production & Manufacturing Research*, vol. 12, no. 1, 2024.
- [3] A. Fischer et al., "Integrated lean and ergonomic assessment for human-centered factory planning," *Procedia CIRP*, vol. 120, pp. 344–349, 2023.
- [4] N. M. Aripin, F. Mahmud, K. L. Lee, and S. Hussain, "Lean ergonomics analysis in SMEs manufacturing sector: A systematic review," *Journal of Technology and Operations Management*, vol. 19, no. 1, pp. 89–108, 2024.
- [5] V. Mayang, M. Hartono, and A. Santoso, "Integration of lean six sigma and ergonomics in internal logistics: A systematic review," *Jurnal Sistem Teknik Industri*, vol. 26, no. 1, pp. 70–78, 2024.
- [6] F. Hussain, M. Uzair, M. A. Islam, and M. Shafiq, "Implementation of ergonomics and lean manufacturing principles to improve work environment and performance," *Journal of Applied Research in Technology & Engineering*, vol. 5, no. 1, pp. 13–22, 2024.
- [7] N. Suranuntchai and P. Chutima, "Lean management and ergonomic consideration to improve manual assembly process," *Engineering Journal*, vol. 27, no. 2, pp. 29–45, 2023.
- [8] Dworschak and H. Zaiser, "Lean ergonomics: An empirical combination of management science and ergonomics," *Zeitschrift für Arbeitswissenschaft*, vol. 77, pp. 515–526, 2023.
- [9] P. Pluchino et al., "Advanced workstations and collaborative robots: Mental workload analysis in assembly tasks," *Frontiers in Robotics and AI*, vol. 10, 2023.
- [10] A. M. Lasota, "Manual palletizing simulation: Time and ergonomic study," *International Journal on Interactive Design and Manufacturing*, vol. 20, pp. 1321–1334, 2025.
- [11] S. Sony, "Lean manufacturing performance measures: A review and research agenda," *International Journal of Productivity and Performance Management*, 2021.
- [12] G. Tortorella and D. Fettermann, "Implementation of Industry 4.0 and lean production in manufacturing systems," *Journal of Manufacturing Technology Management*, 2020.
- [13] R. Shah and P. Ward, "Defining and developing measures of lean production," *Journal of Operations Management*, 2020.
- [14] A. Kumar, S. Sharma, and V. Dixit, "Lean implementation framework for manufacturing industries," *Materials Today: Proceedings*, 2022.
- [15] R. Singh and A. Khanduja, "Ergonomic interventions in manufacturing systems for productivity improvement," *International Journal of Industrial Ergonomics*, 2021.
- [16] S. Gupta and A. Jain, "Smart lean manufacturing using Industry 4.0 technologies," *Journal of Cleaner Production*, 2023.
- [17] M. Patel and K. Desai, "Lean assessment models and performance metrics in manufacturing," *Benchmarking: An International Journal*, 2022.
- [18] A. Yadav, P. Luthra, and D. Garg, "Barriers to lean implementation and their mitigation," *Production Planning & Control*, 2021.
- [19] S. Kumar and R. Singh, "Workstation optimization using lean tools and ergonomic principles," *Procedia Manufacturing*, 2023.
- [20] V. Modi and P. Thakkar, "Lean manufacturing practices and operational performance," *International Journal of Lean Six Sigma*, 2022.