Enhancing Shopfloor Visualization Using Key Quality Management Practices

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Abstract. Effective shopfloor visualization is essential in modern manufacturing, providing real-time insights into production performance, error trends and process optimization opportunities. This paper details the fundamental principles of quality management that enhance shopfloor visualization, including real-time monitoring, error tracking, process analysis, traceability, and continuous improvement. Using visual tools to manage production flow, ensuring work-in-progress is aligned with quality and demand. By integrating these aspects into shopfloor systems, manufacturers can achieve higher efficiency, improved product quality, and data-driven decision-making.

1 Introduction

The evolution of manufacturing has been significantly influenced by Industry 4.0 technologies, with shopfloor visualization emerging as a critical tool for enhancing production efficiency. Numerous studies have explored how real-time data monitoring and digital twin models contribute to improved manufacturing outcomes. The importance of integrating IoT-based sensors to provide continuous feedback on machine performance it is emphasized by [1]. Similarly, in [2] are discussed the predictive analytics as a means of minimizing machine downtime through early failure detection.

Shopfloor visualization constitutes a fundamental pillar of Industry 4.0 and cyber-physical systems (CPS), enabling real‑time decision‑making and operational transparency. Early work in shopfloor management introduced lean dashboards and Key Performance Indicators (KPI) visual boards designed to enhance production visibility and responsiveness. Re-cently, data-oriented and digital shopfloor management paradigms have evolved; for instance, data-oriented management frameworks facilitate holistic operational control across technology, organization and people layers.

Shopfloor visualization practices integrate quality management principles (ISO, Total Quality Management, Lean, Six Sigma) with visual management techniques with the scope to promote transparency, error reduction, and continuous improvement.

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Six Sigma methodology serves as an effective framework for companies aiming to enhance their sustainable manufacturing performance. In parallel, the Lean Six Sigma methodology integrates Lean and Six Sigma principles to minimize waste, maintain high quality, and meet customer expectations [3]. Building on this foundation, the approach has evolved to include environmental management practices, giving rise to Green Lean Six Sigma. Applied within manufacturing processes, Green Lean Six Sigma not only reduces waste and improves quality, but also fosters environmentally sustainable operations. The thematic analysis revealed a principle node centered on data-driven decision-making, emphasizing that data analysis and informed choices should be integral to Lean Six Sigma implementation in the manufacturing sector. All the aspects referring to Data, Decide, Measure, Analyze, Improve, and Drive Decision Making, it highlights the sequential steps involved in this process. Embedding data-driven decision-making within Lean Six Sigma can play a crucial role in advancing environmental economics and management. For instance, analyzing data on energy consumption and waste management enables companies to identify opportunities for minimizing environmental impact and optimizing resource utilization. Furthermore, tracking key performance indicators through data allows organizations to pinpoint inefficiencies and implement targeted strategies that enhance productivity while reducing operational costs.

A recent study developed by [4], it demonstrated that automated quality control systems reduce defect rates, reinforcing the value of AI-driven quality management. Meanwhile, in [5] was explored the role of Six Sigma methodologies in optimizing shopfloor workflows, concluding that structured process analysis leads to substantial productivity gains. Also, an error tracking system was introduced that leverages machine learning to predict and prevent recurring defects, improving production stability [6].

Furthermore, [7] examined AI-based quality assurance systems, showing that automated defect detection can enhance product consistency. There was highlighted the importance of interdepartmental collaboration in shopfloor management, arguing that data-sharing frameworks foster proactive decision-making [8-10]. The effectiveness of the PDCA (Plan-Do-Check-Act) cycle demonstrates its impact on operational efficiency in driving continuous improvements. Additionally, the material traceability has an essential role for improving regulatory compliance and defect prevention.

This paper builds upon these insights by thoroughly examining the fundamental quality management principles that contribute to enhanced shopfloor visualization. It not only explores the theoretical foundations of these principles, but also provides practical, structured frameworks for their effective implementation. By outlining step-by-step strategies and best practices, this study aims to offer a comprehensive guide for organizations seeking to optimize their shopfloor operations through improved visualization techniques.

2 Key quality management points for shopfloor visualization

2.1 Methodology

This study adopts a conceptual and analytical methodology, based on an integrated literature review and cross-comparison of best industrial practices from Lean, Six Sigma, and Visual Quality Management frameworks.

The research process followed three main stages:

- Data collection – Identification and synthesis of recent peer-reviewed studies, industrial reports, and international standards (ISO, Lean, Six Sigma, Industry 4.0 frameworks).

- Comparative analysis – Mapping of overlapping quality management principles relevant to shopfloor visualization, such as process transparency, traceability, and real-time monitoring.
- Framework formulation – Development of a conceptual model linking visualization tools to quality improvement metrics (OEE, defect rate, cycle time, traceability index).

The methodological approach is qualitative and conceptual, aiming to establish a structured analytical foundation for future empirical validation (Figure 1).

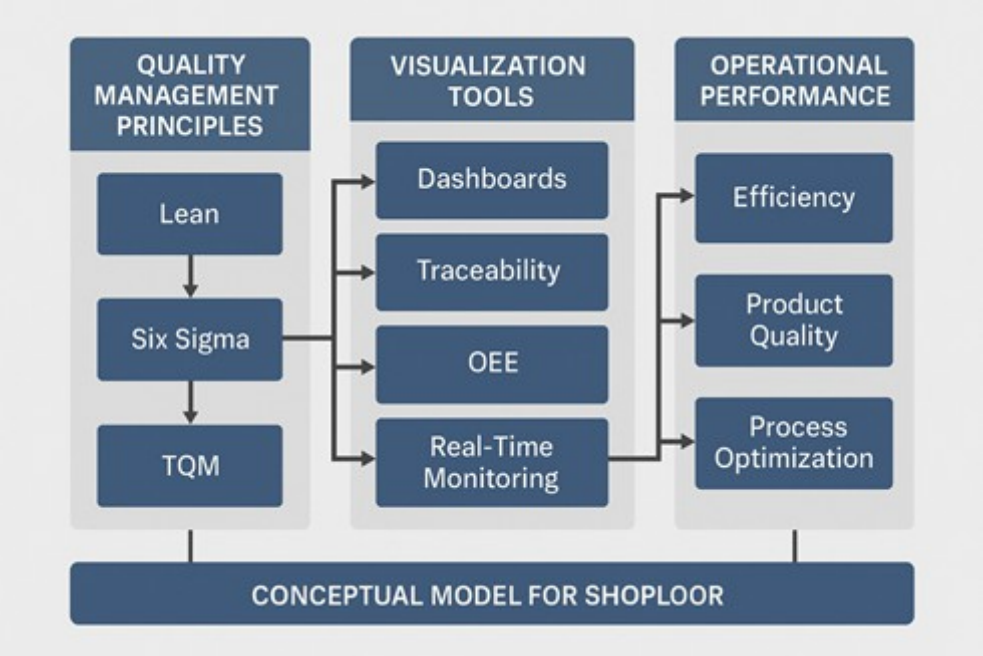

Fig. 1. Real-time performance monitoring flowchart.

2.2 Real-time performance monitoring

Real-time performance monitoring is crucial for maintaining operational efficiency and ensuring that production processes adhere to quality standards. One of the most widely used performance indicators is Overall Equipment Effectiveness (OEE), which measures three key aspects: availability, performance, and quality. Availability represents the uptime of machines, performance assesses operational speed, and quality examines the proportion of defect-free products. By continuously monitoring OEE, manufacturers can identify inefficiencies and implement corrective actions in real-time.

Another critical aspect of real-time monitoring is the assessment of OK or not OK (NOK), and scrap rates. Tracking these indicators provides immediate feedback on product conformance, enabling operators to take swift action in case of deviations. If scrap rates exceed acceptable limits, adjustments can be made to prevent material wastage and improve yield.

Monitoring cycle times is also vital, as discrepancies between planned and actual cycle times can indicate bottlenecks in the production process. A significant variance may suggest issues such as machine malfunctions, operator inefficiencies, or material flow

problems. Real-time dashboards displaying cycle times help ensure that production stays on track and meets planned output targets.

Additionally, machine status visualization is an essential feature of shopfloor monitoring systems. Categorizing machines as Idle, Running, Error, or Offline provides instant insights into their operational state, allowing maintenance teams to respond promptly to breakdowns and minimize downtime.

A systematic flowchart of real-time performance monitoring process it is described in Figure 2.

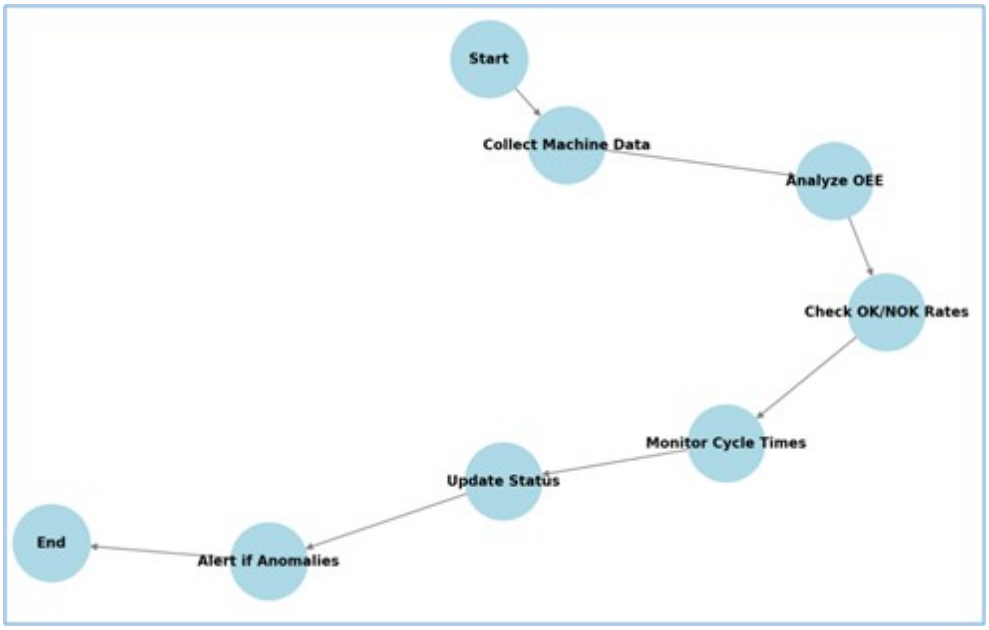

Fig. 2. Real-time performance monitoring flowchart.

2.3 Error history and management

Effective error management is a cornerstone of quality control, ensuring that manufacturing defects and process deviations are promptly addressed. Status and Error Logs play a pivotal role in this process by recording all error messages, system warnings, and performance anomalies. By analyzing historical error data, manufacturers can identify recurring issues and implement long-term corrective measures.

To facilitate quicker diagnosis of issues, graphical representation of errors through trend charts and heat maps helps operators visualize the frequency and distribution of defects. This approach enables pattern recognition and allows engineers to focus on critical problem areas that require immediate intervention.

Automated notifications further enhance error management by sending alerts whenever critical deviations occur. If a machine exceeds predefined operational limits or a production parameter falls out of range, the system triggers an immediate alert, enabling swift corrective actions.

2.4 Process analysis and optimization

Process analysis is fundamental to improving production efficiency and reducing waste. One of the most effective tools for this purpose is the use of customizable charts, which enable manufacturers to analyze process times, pass rates, and defect distributions. By visualizing production trends, operators can identify inefficiencies and take appropriate corrective measures.

Breaking down process times into individual steps allows companies to pinpoint areas where time is wasted or where workflow improvements can be made. By analyzing the duration of each stage (Figure 3), companies can refine production sequences and eliminate unnecessary delays.

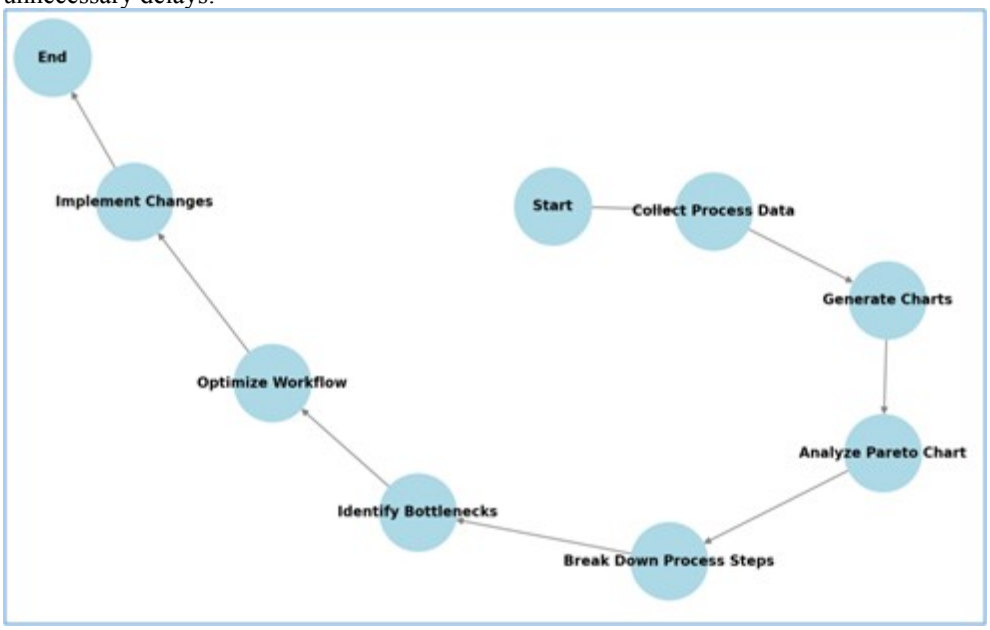

Fig. 3. Process analysis and optimization flowchart.

2.5 Quality control and defect minimization

Maintaining product quality requires continuous monitoring of critical parameters, such as temperature, pressure, and speed. Deviations from optimal values can lead to defects, making real-time tracking essential for maintaining process stability.

Defect analysis integrates qualitative and quantitative data to identify the root causes of quality issues. By employing AI-driven image recognition systems and statistical process control (SPC) techniques, manufacturers can systematically reduce defect rates.

A widely used method for prioritizing defects is the Pareto chart, which applies the 80/20 principle to quality management. By categorizing defects based on their impact, manufacturers can focus on the most significant issues and allocate resources efficiently.

Additionally, automated deviation detection enables shopfloor systems to make real-time adjustments, ensuring that defective products are identified before reaching the final stage of production.

For practical implementation, the following key performance indicators (KPIs) are proposed to monitor the impact of visualization tools (Table 1):

- OEE (Overall Equipment Effectiveness) – measures equipment productivity (target: >85%).

- Defect rate (PPM) – tracks product quality and process stability (target: <500 PPM).
- Mean Time to Repair (MTTR) and Mean Time Between Failures (MTBF) – assess maintenance efficiency.
- Cycle time adherence – ratio of planned vs. actual cycle time, ensuring process consistency.
- Traceability index – measures data integration and material tracking coverage across the production line.

Table 1. Key performance indicators.

Metric	Baseline	Target	Improvement
OEE	70%	88%	+26%
Defect rate (PPM)	2000	900	−55%
Downtime	15%	7%	−53%
Cycle time deviation	±10%	±4%	−60%
Traceability coverage	55%	98%	+43%
Energy consumption per batch	100% baseline	82%	−18%
Maintenance efficiency (MTTR)	6.0 h	4.8 h	−20%
MTBF (Mean Time Between Failures)	150 h	190 h	+27%

3 Conclusions

The theoretical contribution of this paper lies in structuring a unified analytical framework that connects quality management principles with real-time visualization mechanisms. This framework supports industrial decision-making through data transparency and feedback-driven improvement, thus bridging the gap between conceptual models and operational practice.

Shopfloor visualization suppose to a systematic use of visual tools, indicators, and information systems to ensure quality assurance, operational transparency, and continuous improvement in manufacturing environments.

Shopfloor visualization, supported by real-time monitoring, process analysis, and continuous improvement strategies, significantly enhances manufacturing efficiency. By integrating quality management principles, manufacturers achieve better decision-making, defect reduction, and optimized production performance. A well-structured shopfloor visualization system allows for improved response times to operational deviations, reducing downtime and enhancing overall equipment efficiency. Moreover, the implementation of predictive analytics in error management ensures that recurring defects are minimized, contributing to long-term process stability.

Another crucial aspect is the role of interdepartmental collaboration in achieving seamless data integration across production, IT, and quality control teams. Efficient communication through role-specific dashboards ensures that each team has access to relevant data, leading to more informed decision-making. Additionally, real-time material traceability enhances compliance with industry regulations and improves the overall reliability of production processes. Future research should explore AI-driven enhancements for real-time analytics and predictive quality control, as well as the integration of blockchain technology for more secure traceability solutions. By adopting these advancements, manufacturers can stay competitive in an increasingly data-driven industrial landscape.

To further validate the proposed framework, a pilot study is planned within an industrial partner company operating in the automotive components sector. The implementation will focus on a shopfloor dashboard integrating OEE, defect rate, and traceability metrics in real time. Data will be collected over a six-month period to evaluate measurable improvements in productivity, defect reduction, and operator responsiveness. The empirical findings will provide quantitative validation and practical insights to reinforce the theoretical framework introduced in this paper.

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References

1. T.R. Kurfess, C. Saldana, K. Saleeby, M. Parto Dezfouli, *A Review of Modern Communication Technologies for Digital Manufacturing Processes in Industry 4.0*, J. Manuf. Sci. Eng. **142** (2020). Available from: https://doi.org/10.1115/1.4048206
2. A. Hosseinzadeh, F. Frank Chen, M. Shahin, H. Bouzary, *A predictive maintenance approach in manufacturing systems via AI-based early failure detection*, Manufacturing Letters, **35** (2023). Available from: https://doi.org/10.1016/j.mfglet.2023.08.125
3. J. Huang, M. Irfan, S.S. Fatima, R.M. Shahid, *The role of lean Six Sigma in driving sustainable manufacturing practices: An analysis of the relationship between lean six sigma principles, data-driven decision making, and environmental performance*, Front. Environ. Sci., **11** (2023). Available from: https://doi.org/10.3389/fenvs.2023.1184488
4. A. Goyal, *Reducing Defect Rates with AI-Powered Test Engineering and JIRA Automation in Agile Workflows*. International Journal of Current Engineering and Technology, **13** (2023).
5. D. Marsetiya Utama, M. Abirfatin, *Sustainable Lean Six-sigma: A new framework for improve sustainable manufacturing performance*, Cleaner Engineering and Technology, **17** (2023). Available from: https://doi.org/10.1016/j.clet.2023.100700
6. C. Lee, Y. Zhang, X. Chen, *AI-Driven predictive maintenance in smart manufacturing: Enhancing efficiency through deep learning models*, Journal of Information Systems Engineering and Management, **10** (2025).
7. S. Sundaram, A. Zeid, *Artificial Intelligence-Based smart quality inspection for manufacturing,* Micromachines, **14** (2023), Available from: https://doi.org/10.3390/mi14030570
8. M. Zuefle, C. Rennpferdt, D. Krause, *Cross-departmental and cross-disciplinary product development – An industry survey on the necessity and future development of cross-departmental and cross-disciplinary perspectives*, Procedia CIRP, **11** (2021). Available from: https://doi.org/10.1016/j.procir.2021.05.147
9. J. Antony, Six Sigma vs. Lean: *Some Perspectives from Leading Academics and Practitioners*, International Journal of Productivity and Performance Management, **60** (2011). Available from: https://doi.org/10.1108/17410401111101494
10. S.B. Rane, S. Wavhal, P.R. Potdar, *Integration of Lean Six Sigma with Internet of Things (IoT) for productivity improvement: A case study of contactor manufacturing industry*, Int J Syst Assur Eng Manag, **14** (2023). Available from: https://doi.org/10.1007/s13198-023-01980-7