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Article

Leading with excellence: Critical leadership dimensions in Lean Six Sigma for business excellence

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Abstract: In today's competitive and complex business environment, achieving business excellence requires a combination of effective methodologies and strong leadership to drive and sustain organizational transformation. Lean Six Sigma (LSS), a proven methodology for improving operational efficiency, relies on effective leadership for successful implementation and lasting impact. This study examines how the integration of Lean, Six Sigma, and Total Quality Management (TQM) shapes leadership strategies that enhance organizational agility, resilience, and responsiveness to market dynamics. It highlights the crucial role of leadership in fostering collaboration, optimizing resource utilization, and cultivating a culture of continuous improvement. The study introduces the Structured Lean Leadership Framework as a strategic tool to develop the leadership capabilities essential for LSS success, addressing challenges such as weak leadership commitment, resistance to change, and communication barriers. Through the application of the DMAIC framework, Key Performance Indicators (KPIs), and Voice of Customer (VOC) analysis, the research aligns LSS with business objectives, customer needs, and sustainability goals. Additionally, it explores how combining LSS with Agile methodologies can improve operational efficiency, governance, and innovation, helping organizations better navigate future challenges. This research offers valuable insights for executives, practitioners, and researchers, supporting leadership development, data-driven decision-making, and long-term value creation. Future studies should focus on validating the Structured Lean Leadership Framework, exploring Agile-LSS integration in regulated industries, and examining the impact of Industry 4.0 technologies on LSS and leadership.

Keywords: effective leadership; lean leadership; TQM; LSS; DMAIC; continuous improvement

1. Introduction

In today's competitive and complex business environment, adopting quality improvement programs is essential to meet the increasing demand for high product quality (Shafiq et al., 2019). Achieving business excellence requires a combination of effective methodologies and strong leadership to drive sustainable organizational transformation. To stay competitive, organizations must integrate frameworks like Lean Six Sigma (LSS) with visionary leadership to align strategic goals and foster a culture of continuous improvement. While LSS focuses on optimizing efficiency, reducing waste, and improving processes, its success hinges on leadership that ensures effective implementation and long-term impact. Strong leadership provides direction, empowers teams, and embeds LSS principles into the organizational culture, creating an environment where data-driven decision-making and employee engagement can thrive. Leadership is crucial for fostering innovation, accountability, and adaptability, which are essential for maintaining business excellence (Gomaa, 2025c).

Leadership is the ability to inspire, guide, and empower individuals or teams to achieve organizational goals. It involves motivating others, influencing their behavior, and providing the resources, confidence, and authority needed for success. Effective leadership aligns individual efforts with broader objectives, fostering a sense of purpose and driving performance. By creating an environment where people feel valued, supported, and motivated, leaders help their teams reach their full potential (Fok-Yew and Hamid, 2021). According to Laureani and Antony (2019), leadership could be classified into the five leadership theories that derived from most of the literature review. First is the behavioral perspective, it classifies leaders' behaviors into two clusters either task-oriented or people-oriented. Second is the contingency perspective, it believes powerful leaders will accommodate their leadership styles to the situation. Third is the competency perspective, it attempts to find the personality traits of effective leaders. Fourth is transformational perspective, it declares that leaders set and convey a vision. Fifth is the implicit leadership perspective, it conveys the significance of leadership is inflated and considers the human need for control.

In the manufacturing sector, Strategic Lean Leadership plays a key role in driving efficiency, innovation, and sustainable growth. Lean Six Sigma (LSS), which combines Lean's waste reduction with Six Sigma's data-driven problem-solving, offers a systematic approach to process optimization and quality enhancement. However, the success of LSS depends not only on its tools but also on leadership that aligns organizational goals, engages employees, and supports continuous improvement.

Lean leadership guides this transformation by providing strategic direction, empowering teams, and embedding Lean principles within the organizational culture. Without strong leadership, LSS adoption can become inconsistent, limiting its potential. Lean leadership fosters continuous improvement by aligning strategic vision, team empowerment, and structured problem-solving, helping organizations reduce waste, optimize processes, and enhance quality.

This study examines the role of Strategic Lean Leadership in driving Lean Six Sigma success for manufacturing excellence. It introduces a Structured Lean Leadership Framework, identifies key leadership competencies, and addresses challenges in LSS adoption. The study also presents the LSS-DMAIC framework (Define, Measure, Analyze, Improve, Control) for sustained process improvement, while integrating Agile methodologies and digital transformation to ensure adaptability. The paper is structured as follows: Section 2 reviews leadership and LSS literature, Section 3 identifies research gaps, Section 4 outlines the methodology and introduces the LSS leadership framework, and Section 5 presents strategic insights, recommendations, and future research directions.

2. Literature review

Lean principles focus on enhancing operational efficiency by optimizing quality, speed, and cost while eliminating waste (muda), unevenness (mura), and overburden (muri). Effective Lean leadership is crucial for fostering continuous improvement, empowering employees, and enabling decentralized decision-making (Aij and Teunissen, 2017; Gomaa, 2024).

Dombrowski and Mielke (2013, 2014) introduced a Lean leadership model based on five core principles: improvement culture, self-development, qualification, gemba, and hoshin kanri. These principles emphasize the importance of frontline engagement, continuous learning, and strategic alignment to drive long-term improvements.

Laureani and Antony (2019) explored the integration of Lean and Six Sigma (LSS), which combines Lean's waste reduction and Six Sigma's data-driven precision. A review of 179 papers highlighted that leadership is key to successful LSS deployment and stressed the need for leadership models aligned with LSS principles.

Fok-Yew and Hamid (2021) examined the Baldrige Excellence Model in Malaysia's E&E manufacturing sector, finding that strategy, operations, and Lean practices significantly influence business excellence. The study suggests future research into leadership behaviors and the impact of Industry 4.0 on other industries.

Karakose et al. (2022) analyzed 221 studies on Distributed Leadership (DL) in schools, revealing a shift from early focuses on school improvement and instructional leadership to innovation and capacity-building in response to increasing educational complexity.

Karakose et al. (2023) reviewed 300 studies on Transformational School Leadership (TSL), noting a transition from conceptualizing TSL to focusing on principals, instructional leadership, and digital competencies. Emerging themes include work-family conflict, learning culture, and the underexplored areas of mentoring and teacher leadership.

Yirci et al. (2023) reviewed 121 articles on mentoring in school leadership, identifying a shift from professional development to enhancing leadership skills and advancing social justice. Mentoring is recognized as essential for developing sustainable school leadership.

LSS integrates Lean's focus on waste reduction with Six Sigma's data-driven precision to optimize processes. The DMAIC framework (Define, Measure, Analyze, Improve, Control) provides a structured approach to continuous improvement. **Table 1** outlines key LSS tools, such as 5S, Root Cause Analysis, Hoshin Kanri, and VOC, that support decision-making, customer satisfaction, and operational excellence (Gomaa, 2023b, 2023c, 2023d).

Table 1. Key LSS tools in manufacturing.

#	Tool	Description	Objective
1	5S / 6S	Visual control	Organize and standardize the workspace.
2	5 Whys	Root cause analysis	Identify causes by repeatedly asking "why."
3	7QC Tools	Quality control methods	Improve product quality using statistical tools.
4	8 Wastes	Lean waste analysis	Eliminate inefficiencies in processes.
5	ABC	Pareto classification	Categorize items by frequency or significance.
6	ABC-XYZ	Advanced classification	Enhance inventory and resource optimization.
7	Andon	Visual control device	Provide real-time production feedback.
8	ANOVA	Variance analysis	Compare group means for decision-making.
9	Benchmarking	Performance comparison	Assess against industry best practices.
10	Bottleneck	Constraint analysis	Identify and resolve process bottlenecks.
11	C&E Diagram	Cause-and-effect analysis	Visualize root causes of problems.

Table 1. (*Continued*).

#	Tool	Description	Objective
12	CBA	Cost-benefit analysis	Evaluate financial impact of decisions.
13	Charts	Process control charts	Monitor process stability over time.
14	COPQ	Cost of Poor Quality	Quantify losses due to inefficiencies.
15	Cpk	Process capability	Measure how well a process meets specs.
16	CSA	Customer satisfaction	Analyze feedback to improve quality.
17	CTQ	Critical to Quality	Identify key quality factors.
18	DMAIC	Improvement methodology	Define, Measure, Analyze, Improve, Control.
19	DMADV	Process design	Define, Measure, Analyze, Design, Validate.
20	DOE	Design of experiments	Optimize processes through controlled testing.
21	Fishbone	Ishikawa diagram	Identify potential causes of issues.
22	FMEA	Failure mode analysis	Prioritize failure risks in a process.
23	Gage R&R	Measurement analysis	Assess variation in measurement systems.
24	Gantt	Project timeline	Visualize tasks and milestones.
25	Gemba	Go & see	Observe processes firsthand.
26	Heijunka	Workload leveling	Balance production to reduce inefficiencies.
27	Hoshin Kanri	Strategic alignment	Link company goals with daily actions.
28	Jidoka	Automated detection	Enable machines to detect & fix issues.
29	JIT	Just-in-Time	Minimize inventory by producing on demand.
30	Kaizen	Continuous improvement	Drive small, ongoing enhancements.
31	Kanban	Visual workflow	Manage inventory and tasks effectively.
32	KANO	Customer satisfaction model	Prioritize features based on user needs.
33	KPIs	Performance tracking	Measure progress against business goals.
34	Mapping	Process mapping	Visualize workflows (SIPOC, flowchart).
35	OEE	Equipment effectiveness	Assess machine performance.
36	Pareto	Pareto chart	Identify key problem areas.
37	PDCA	Problem-solving cycle	Plan, Do, Check, Act for improvements.
38	Poka-Yoke	Mistake proofing	Prevent defects and errors.
39	QFD	Quality function deployment	Translate customer needs into specs.
40	RACI	Responsibility matrix	Define roles in projects.
41	RCA	Root cause analysis	Identify sources of process issues.
42	SIPOC	High-level mapping	Define Suppliers, Inputs, Process, Outputs, Customers.
43	SMART	Goal setting	Specific, Measurable, Achievable, Relevant, Time-bound.
44	SMED	Rapid changeover	Reduce equipment setup time.
45	Standard Work	Best practice documentation	Ensure consistency in processes.
46	Taguchi	Robust design	Minimize process variation.
47	Takt Time	Production pacing	Align production rate with demand.
48	TQM	Total quality management	Foster company-wide quality culture.
49	TPM	Total productive maintenance	Maximize equipment reliability.
50	Value-Added	Process efficiency	Identify value-adding activities.
51	VOC	Voice of Customer	Capture and analyze customer needs.
52	VOP	Voice of Process	Assess and enhance process performance.
53	Sigma Level	Process capability	Measure performance using Six Sigma.

2.1. Critical failure factors in Lean Six Sigma (LSS) projects

Lean Six Sigma (LSS) is well-known for enhancing efficiency and quality, but its implementation often faces significant obstacles. Common challenges include resistance to change, lack of leadership support, insufficient training, and resource limitations. These barriers have been identified as critical to successful LSS adoption (Albalkhy et al., 2021a, 2021b; Alnadi et al., 2021; Connor, 2022; Dursun et al., 2022; Erne, 2022; Ikuabe et al., 2022; Lima et al., 2023; Moradi et al., 2024; Thakkar et al., 2021). Addressing these challenges early improves the likelihood of successful implementation. **Table 2** identifies key failure factors, emphasizing the need for strong leadership, clear objectives, training, and communication to achieve sustainable improvements and operational excellence.

1) Customer-Related Challenges: LSS initiatives often struggle to align with customer needs due to incomplete requirements, changing specifications, and limited feedback. Implementing Voice of Customer (VOC) analysis and proactive engagement helps ensure improvements match customer expectations.
2) Leadership and Organizational Challenges: Effective leadership is crucial for LSS success. Many projects fail due to insufficient executive support, unclear objectives, and resistance to change. Establishing strategic alignment, clear KPIs, and robust governance frameworks strengthens project execution.
3) Resource and Supply Chain Constraints: Shortages in materials, skilled personnel, and procurement delays hinder LSS progress. Strengthening supplier relationships, optimizing resource management, and employing data-driven tools can alleviate these constraints.
4) Workforce and Change Management Challenges: An engaged and well-trained workforce is essential for LSS success. Challenges like inadequate training, resistance to change, and high turnover can undermine efforts. Investing in training programs and promoting a culture of continuous improvement is key.
5) IT Infrastructure Deficiencies: Weak IT infrastructure, limited digital tools, and poor integration of smart solutions can impede LSS efforts. Enhancing IT systems with AI-driven analytics, real-time monitoring, and automation improves decision-making and process optimization.
6) Financial Constraints and Cost Management: Budget limitations and poor cost control are significant barriers to successful LSS implementation. Organizations must align financial strategies with LSS goals, optimize inventory, and track ROI to ensure long-term sustainability and profitability.

In conclusion, the success of LSS projects requires a holistic approach that integrates leadership commitment, resource optimization, workforce development, IT enablement, and financial sustainability. By addressing these critical failure factors proactively, organizations can drive sustained improvements, reduce costs, and foster a culture of continuous improvement, ultimately achieving operational excellence and a competitive edge.

Table 2. Critical failure factors, objectives, and strategic alignment in LSS projects.

#	Perspective	Objective	Strategic Alignment	Critical Failure Factors
1	Customer/Client	Align LSS with customer expectations to enhance satisfaction and engagement.	Customer-Centric Approach: Integrates VOC, stable requirements, and satisfaction metrics.	1) Misaligned objectives. 2) Unclear or changing requirements. 3) Lack of satisfaction measurement. 4) Limited customer involvement. 5) Unrealistic expectations.
2	Management/ Leadership	Establish leadership-driven continuous improvement and accountability.	Leadership & Governance: Ensures executive support, strategic vision, and structured decision-making.	6) Weak leadership commitment. 7) Lack of clear strategy. 8) No benchmarking. 9) Poor KPIs and monitoring. 10) No standardized processes. 11) Inadequate project management. 12) Limited LSS training. 13) Weak planning and risk control. 14) Undefined roles. 15) Poor communication. 16) Resistance to change.
3	Resources & Supply Chain	Optimize resources and supplier collaboration for LSS success.	Operational Efficiency & Resilience: Focuses on resource planning, supplier engagement, and waste reduction.	17) Insufficient resources. 18) Equipment issues. 19) Inefficient utilization. 20) Supply chain delays. 21) Weak supplier relationships. 22) Over-reliance on subcontractors. 23) Supplier resistance to Lean.
4	Workforce	Develop a skilled and motivated workforce.	Talent Development & Change Readiness: Emphasizes training, engagement, and Lean adoption.	24) Skills shortage. 25) Low motivation. 26) Inadequate training. 27) Resistance to change. 28) High turnover.
5	IT Infrastructure	Leverage digital transformation for LSS efficiency.	Technology & Smart Manufacturing: Supports automation, analytics, and process optimization.	29) Limited IT systems and analytics. 30) Weak digital integration.
6	Financial	Ensure cost-effective and sustainable LSS implementation.	Financial Viability & ROI Optimization: Aligns cost control with performance tracking.	31) Budget constraints. 32) High operational costs.

2.2. LSS Studies in manufacturing industries

Lean Six Sigma (LSS) methodologies are widely adopted across various sectors, particularly in manufacturing, maintenance, quality improvement, and sustainability. The studies in **Tables 3** and **4** categorize LSS applications based on key objectives and contributions:

1) Manufacturing Process Optimization: LSS improves efficiency, reduces defects, and controls costs in industries such as medical equipment, steel, and textiles, leading to enhanced operational performance (Gomaa, 2024; Singh, 2024; Tsarouhas, 2023).
2) Lean Implementation & Waste Reduction: LSS strategies effectively reduce waste and improve efficiency in automotive, tire manufacturing, and packaging, boosting productivity and maintaining quality (Oliveira, 2023; Sasikumar, 2023).
3) Project Management & Shutdown Optimization: LSS optimizes project execution and minimizes downtime in off-site manufacturing and dairy industries, reducing operational disruptions (McDermott, 2024; Trubetskaya, 2024).

4) Maintenance & Reliability Improvement: LSS enhances equipment reliability and optimizes maintenance processes in industries such as petrochemical and pharmaceutical, improving productivity and reducing downtime (Gomaa, 2023; West, 2023).
5) Quality & Performance Enhancement: LSS improves product quality by reducing rejection rates and scrap levels, contributing to better quality standards in textiles and spare parts (Altug, 2023; Jimenez, 2023).
6) Sustainability & Energy Efficiency: LSS supports sustainability and energy efficiency in industries like carrageenan production, promoting environmentally responsible operations (Andron, 2023; Utama, 2023).

In the 2024–2025 period, LSS integrates with Industry 4.0, leveraging AI-driven predictive decision-making. Studies by Amjad et al. (2024) and Kumar et al. (2024) highlight the role of AI in predictive maintenance and defect detection. Gomaa (2025) introduces Lean 4.0 and LSS 4.0, combining AI, IoT, blockchain, and digital twins to enable predictive process control.

In conclusion, LSS continues to drive operational excellence and efficiency across industries, with evolving integration of Industry 4.0 technologies to enhance decision-making and innovation.

Table 3. Lean Six Sigma (LSS) studies in manufacturing industries (2023–2024).

#	Reference	Contribution	Application	Key Objectives
1	Singh, 2024	Environmental LSS framework	Medical equipment manufacturing	Improve capacity utilization, air quality
2	Srinivasan, 2024	LSS framework for manufacturing	Steel industry	Reduce NVA time, improve efficiency
3	Gomaa, 2024	LSS framework for manufacturing	Spare parts company	Improve OEE %, sigma level
4	McDermott, 2024	LSS for project management (PM)	Off-site manufacturing	Reduce time, cost
5	Trubetskaya, 2024	DMAIC for shutdown projects	Dairy industry	Reduce downtime
6	Jurewicz, 2024	TPM framework	Machinery fleet	Improve OEE
7	Trubetskaya, 2024	DMAIC for maintenance	Dairy industry	Reduce maintenance downtime
8	Macalinao, 2024	TPM framework	Pharmaceutical manufacturing	Reduce maintenance downtime
9	Gomaa, 2023d	LSS framework for manufacturing	Spare parts company	Improve OEE %, quality %
10	Abdullahi, 2023	Lean construction framework	Construction project	Improve efficiency, effectiveness
11	Tsarouhas, 2023	Six Sigma framework	Olive packaging	Minimize defects, reduce cost
12	Altug, 2023	Six Sigma framework	Spare parts company	Improve performance, reduce lead time
13	Andron, 2023	Kaizen framework for energy	Refrigeration company	Increase energy efficiency
14	Conde, 2023	LSS framework for manufacturing	Car parts manufacturing	Reduce defects
15	Enache, 2023	LSS framework for manufacturing	Metal door manufacturing	Reduce scrap rate
16	Habib, 2023	Lean framework	Labeling & packaging	Reduce lead time, improve effectiveness
17	Jimenez, 2023	LSS framework	Textile sector	Improve quality, productivity
18	Mittal, 2023	Six Sigma framework	Rubber weather strips	Reduce rejection rate, cost
19	Oliveira, 2023	Lean framework	Automotive assembly	Reduce setup time
20	Sasikumar, 2023	LSS framework	Bias tire manufacturing	Reduce waste, improve OEE
21	Satolo, 2023	LSS framework	Milking processes	Reduce defects %, cost

Table 3. (*Continued*).

#	Reference	Contribution	Application	Key Objectives
22	Toki, 2023	LSS - Quick Changeover framework	Ready-made garments	Improve efficiency, reduce cost
23	Trubetskaya, 2023	LSS framework	Animal feed manufacturing	Reduce inventory, lead time
24	Utama, 2023	Sustainable LSS framework	Carrageenan production	Improve sustainability index
25	Gomaa, 2023	LSS DMAIC framework for maintenance	Petrochemical company	Improve OEE, reliability
26	Al Farihi, 2023	Lean maintenance framework	Wiring harness production	Reduce unplanned downtime, MTTR
27	Shannon, 2023	LSS for maintenance	Pharmaceutical plant	Improve OEE, reduce corrective maintenance
28	West, 2023	LSS for maintenance process	Oil service company	Improve efficiency, increase availability

Table 4. Summary of LSS applications across industries (2023–2024).

#	Category	Reference(s)	Industry/Application	Key Contributions
1	Manufacturing Process Optimization	Gomaa (2024); Jimenez (2023); Mittal (2023); Satolo (2023); Singh (2024); Srinivasan (2024); Toki (2023); Tsarouhas (2023)	Medical equipment, steel, spare parts, textiles, packaging, rubber weather strips, garments, milking	Increased OEE, improved process efficiency, reduced defects, minimized NVA time, reduced costs
2	Lean Implementation & Waste Reduction	Conde (2023); Habib (2023); Oliveira (2023); Sasikumar (2023)	Automotive, tire manufacturing, car parts, labeling & packaging	Reduced setup time, minimized waste, improved OEE, reduced process defects & lead time
3	Project Management & Shutdown Optimization	McDermott (2024); Trubetskaya (2024)	Off-site manufacturing, dairy industry	Reduced project duration, minimized shutdown downtime, cost optimization
4	Maintenance & Reliability Improvement	Al Farihi (2023); Gomaa (2023); Jurewicz (2024); Macalinao (2024); Shannon (2023); Trubetskaya (2024); West (2023)	Machinery fleets, petrochemical, wiring harness, pharmaceuticals, oil services, dairy industry	Improved OEE & reliability, reduced unplanned downtime, optimized maintenance efficiency
5	Quality & Performance Enhancement	Altug (2023); Enache (2023); Jimenez (2023)	Spare parts, metal doors, textiles	Reduced rejection & scrap rates, enhanced quality & productivity
6	Sustainability & Energy Efficiency	Andron (2023); Utama (2023)	Carrageenan production, refrigeration	Enhanced sustainability index, increased energy efficiency

3. Research gap analysis

Despite the widespread adoption of Lean Six Sigma (LSS), several key research gaps remain, particularly in relation to strategic leadership's role in ensuring project success. **Table 5** highlights the following areas for further exploration to enhance Lean leadership practices and improve LSS implementation:

1) Cross-functional Collaboration: Effective collaboration across departments is essential for LSS success, but organizations often struggle with integration. Research should explore leadership strategies that promote teamwork and optimize cross-departmental collaboration for better LSS outcomes.
2) Scaling LSS: Expanding LSS beyond individual projects is challenging due to issues with standardization and integration. Future studies should focus on leadership approaches that enable the consistent and effective scaling of LSS across the organization.

3) Balancing Short-term and Long-term Goals: Leaders face the challenge of balancing quick results with long-term objectives. Research should investigate leadership strategies that achieve short-term successes while ensuring alignment with the organization's broader strategic goals.
4) Employee Development and Knowledge Retention: Successful LSS implementation relies on continuous employee development and knowledge retention. Future research should explore leadership strategies to foster training, skill-building, and the retention of lessons learned from LSS projects.
5) Overcoming Resistance: Organizational resistance to LSS is a common barrier. Research should explore how leadership can engage employees, overcome resistance, and drive cultural change toward embracing LSS principles.
6) Sustaining Momentum Post-Implementation: Maintaining momentum after initial success is a challenge. Future studies should examine leadership strategies for sustaining engagement and ensuring long-term commitment to continuous improvement.
7) Aligning LSS with Organizational Strategy: LSS must be closely aligned with an organization's strategic objectives. Research should explore leadership approaches that ensure LSS initiatives support broader business goals and contribute to long-term organizational success.
8) Cultural Adaptation: Adapting LSS to diverse cultural contexts is essential for global organizations. Future research should explore how leaders can guide the cultural adaptation of LSS practices to ensure their effectiveness across different regions.
9) Supplier and Partner Collaboration: Strong external collaborations are critical for LSS success. Research should investigate leadership strategies that enhance collaboration with suppliers and partners, ensuring alignment with LSS goals.

In conclusion, addressing these research gaps will help advance Lean leadership in LSS projects. By focusing on these areas, organizations can enhance their ability to drive sustainable operational excellence, continuous improvement, and long-term success.

Table 5. Research gap analysis.

#	Research Gap	Challenges	Future Research Directions
1	Cross-Functional Collaboration	Lack of integration between departments.	Study leadership approaches to enhance cross-functional teamwork in LSS projects.
2	Scaling LSS Across the Organization	Difficulty in applying LSS principles organization-wide.	Focus on leadership strategies for scaling LSS across all levels.
3	Balancing Short-Term and Long-Term Goals	Balancing immediate results with long-term goals.	Investigate leadership strategies for aligning short-term wins with long-term objectives.
4	Employee Development and Knowledge Retention	Challenges in maintaining workforce development.	Research leadership's role in employee training and knowledge retention.
5	Overcoming Organizational Resistance	Employee resistance due to lack of leadership engagement.	Explore leadership strategies to overcome resistance and drive cultural change.
6	Sustaining Momentum Post-LSS Implementation	Decline in engagement after initial success.	Study leadership approaches to maintain long-term momentum and continuous improvement.
7	Aligning LSS with Organizational Strategy	Difficulty integrating LSS with overall business strategy.	Research leadership's role in aligning LSS with strategic business goals.

Table 5. (*Continued*).

#	Research Gap	Challenges	Future Research Directions
8	Cultural Adaptation of LSS Practices	Adapting LSS to diverse cultural contexts.	Investigate leadership strategies for cultural adaptation of LSS.
9	Supplier and Partner Collaboration in LSS Projects	Lack of alignment between internal teams and external partners.	Study leadership strategies for enhancing collaboration with suppliers and partners.

4. Research methodology

The success of Lean Six Sigma (LSS) projects in manufacturing is driven by a leadership-centered approach that integrates strategic vision, data-driven decisions, and a culture of continuous improvement. This methodology outlines a framework to optimize operational efficiency, enhance quality, and achieve strategic goals in complex industrial environments. It consists of six key components:

1) Strategic Lean Leadership in LSS Projects: Leadership is a critical factor in LSS success. This component emphasizes the development of leadership competencies such as strategic vision, change management, workforce engagement, and agile decision-making. Effective leadership ensures alignment with organizational goals, facilitates successful project execution, and sustains long-term improvements.
2) Core Principles of Strategic Lean Leadership: LSS leadership follows principles that prioritize efficiency, quality, and sustainability. These principles align projects with customer expectations, technological advances, and business strategies. Leaders foster continuous improvement, innovation, and operational excellence in ever-changing manufacturing environments.
3) DMAIC Framework Integration: The DMAIC methodology (Define, Measure, Analyze, Improve, Control) offers a structured approach to problem-solving and process optimization. Leadership ensures the smooth execution of DMAIC, enabling data-driven decisions and delivering measurable operational improvements.
4) Key Performance Indicators (KPIs) for LSS Leadership: Establishing clear KPIs is vital to evaluating leadership effectiveness. This component identifies metrics that assess leadership's impact on operational efficiency, quality improvements, team collaboration, and project success. These insights help refine leadership strategies and enhance project outcomes.
5) Voice of Customer (VOC) Analysis in LSS Projects: VOC analysis ensures that LSS projects remain customer-focused. By aligning project scope, schedule, quality, safety, and cost with customer expectations, organizations can enhance efficiency, improve quality, and achieve higher customer satisfaction.
6) Integrating Agile Methodologies with LSS: Combining Agile methodologies with LSS creates opportunities to improve efficiency and adaptability. A structured integration approach balances Agile's flexibility with LSS's structured problem-solving, fostering innovation, responsiveness, and operational excellence.

This methodology, by integrating Lean Six Sigma with strategic leadership principles, promotes continuous improvement, data-driven decisions, and sustainable operational excellence in modern manufacturing environments.

4.1. Strategic Lean Leadership in LSS projects

Strategic Lean Leadership is crucial for the success of Lean Six Sigma (LSS) projects, providing the vision and direction necessary to drive manufacturing excellence and continuous improvement. While LSS methodologies like DMAIC (Define, Measure, Analyze, Improve, Control) offer structured frameworks, it's leadership that ensures these methods are implemented effectively and sustained within an organization. Strong leadership fosters cross-functional collaboration, aligns resources, and integrates digital technologies to optimize processes and enhance business performance. As shown in **Table 6**, organizations investing in leadership development for LSS projects experience faster adoption, improved employee engagement, and sustained productivity gains.

1) Strategic Vision and Alignment: Effective Lean leadership requires a clear vision that aligns LSS initiatives with broader organizational goals. Leaders must anticipate market trends, incorporate sustainable strategies, and leverage technologies such as AI and big data analytics to drive efficiency and maintain a competitive advantage.
2) Change Management and Cultural Transformation: Resistance to change is a major barrier in LSS adoption. Strong leadership fosters a culture of continuous improvement and innovation, implementing clear communication, leadership commitment, and workforce training to integrate Lean principles into the organization's culture and ensure long-term success.
3) Workforce Engagement and Empowerment: Employee involvement is vital to LSS success. Lean leaders encourage cross-functional collaboration, problem-solving, and knowledge sharing, empowering employees and recognizing their contributions. This boosts motivation and drives continuous operational improvements.
4) Data-Driven Decision-Making and Agility: Lean leaders must embrace data-driven decision-making, using real-time analytics and predictive modeling to address problems proactively, mitigate risks, and optimize performance. Agile decision-making helps organizations quickly adapt to challenges, ensuring LSS success.
5) Integration of LSS Methodologies: Leadership must ensure the seamless integration of LSS methodologies into organizational strategy and project execution. This includes aligning teams, optimizing workflows, and using DMAIC for structured problem-solving, maximizing Lean's impact on efficiency and productivity.
6) Future Leadership in LSS: As industries evolve, Lean leadership must adapt to emerging technologies like IoT and automation. Leaders will need to balance efficiency with sustainability, ensuring LSS practices align with environmental and social responsibilities while fostering innovation and operational excellence.

In conclusion, strategic Lean Leadership is fundamental to the success of LSS projects, ensuring organizations achieve operational excellence and continuous improvement. By prioritizing vision, change management, employee engagement, and agile decision-making, leaders maximize LSS impact and drive sustainable performance. In the face of digital transformation, organizations with strong leadership in LSS will gain a competitive edge and ensure long-term success.

Table 6. Strategic Lean Leadership in LSS projects.

#	Key Area	Objective	Description
1	Strategic Vision & Alignment	Integrate LSS with organizational goals	Establish a clear vision for sustainability, digital transformation, and efficiency.
2	Change Management	Overcome resistance, drive Lean culture	Implement leadership commitment, structured change strategies, and training.
3	Workforce Empowerment	Foster engagement and collaboration	Promote ownership, cross-functional teamwork, and knowledge sharing.
4	Data-Driven Agility	Enable proactive decision-making	Utilize real-time analytics and digital tools for process optimization.
5	LSS Methodology Integration	Ensure structured execution	Align DMAIC and process frameworks with strategic objectives.
6	Future Leadership & Innovation	Adapt to technology and sustainability	Leverage AI, IoT, and hybrid models while maintaining a people-centric approach.

4.2. Core principles of Strategic Lean Leadership in LSS projects

Strategic Lean Leadership in Lean Six Sigma (LSS) projects is built on key principles that drive efficiency, quality, and sustainable success. As shown in **Table 7**, these principles ensure that LSS projects are optimized for performance and aligned with customer expectations, technological advancements, and organizational strategy.

1) Customer-Driven Value Creation: Align LSS projects with customer needs using tools like Voice of the Customer (VoC) and the Kano Model, focusing on long-term value and sustainability.
2) Data-Driven Decision-Making: Utilize AI, machine learning, and predictive analytics to optimize performance, anticipate risks, and make informed, proactive decisions.
3) Dynamic Continuous Improvement (Kaizen): Implement real-time feedback loops and digital automation to support iterative improvements, scaling beyond traditional Kaizen methods.
4) End-to-End Waste Elimination: Apply Lean's waste reduction principles to both digital and operational inefficiencies, streamlining workflows and integrating automation to maximize efficiency.
5) Variability Reduction & Process Stability: Leverage predictive modeling and real-time analytics to reduce process variability and ensure consistency in project outcomes.
6) Integrated Stakeholder Engagement: Use AI-driven analytics and dynamic stakeholder mapping to align and engage teams, suppliers, and regulators for enhanced collaboration and alignment.
7) Smart Process Standardization & Control: Ensure consistent global quality through Statistical Process Control (SPC), control charts, and cloud-based monitoring systems.

8) Empowered Workforce & Digital Collaboration: Foster a high-performance culture by enabling digital collaboration, empowering teams with AI-driven insights, and applying agile methodologies to improve contributions and innovation.
9) Predictive Failure Prevention & Risk Mitigation: Use machine learning-based Failure Mode and Effects Analysis (FMEA) and root cause analysis to proactively identify and mitigate risks before they impact outcomes.
10) Agile-LSS Integration for Adaptive Execution: Combine Lean Six Sigma with Agile methodologies to ensure process optimization while maintaining flexibility to adapt to changing business conditions.

In conclusion, these principles reshape Strategic Lean Leadership by integrating data-driven decision-making, digital transformation, and stakeholder collaboration. By leveraging AI, predictive analytics, and real-time adaptability, Lean leaders can drive efficiency, reduce risks, and sustain excellence in a competitive global market.

Table 7. Core principles of Strategic Lean Leadership in LSS projects.

#	Core Principle	Description	Key Focus Areas
1	Customer-Driven Value Creation	Ensures LSS projects align with customer expectations and long-term value.	VoC, Kano Model, sustainability, customer experience.
2	Data-Driven Decision-Making	Leverages AI, machine learning, and predictive analytics to enhance project outcomes.	Real-time monitoring, risk forecasting, performance optimization.
3	Dynamic Continuous Improvement (Kaizen)	Embeds real-time feedback loops for iterative process optimization.	Digital automation, real-time insights, adaptive learning.
4	End-to-End Waste Elimination	Reduces physical, digital, and operational inefficiencies across processes.	Lean waste categories, automation, workflow optimization.
5	Variability Reduction & Process Stability	Enhances consistency through AI-driven predictive modeling and adaptive controls.	Six Sigma, real-time analytics, dynamic simulations.
6	Integrated Stakeholder Engagement	Ensures proactive alignment, collaboration, and engagement across all stakeholders.	AI-driven analytics, expectation mapping, risk alignment.
7	Smart Process Standardization & Control	Uses digital tools to maintain global consistency and quality.	SPC, control charts, cloud-based quality assurance.
8	Empowered Workforce & Digital Collaboration	Fosters innovation, autonomy, and real-time collaboration through technology.	AI-driven insights, agile teams, knowledge sharing.
9	Predictive Failure Prevention & Risk Mitigation	Uses advanced analytics for early risk detection and proactive issue resolution.	Machine learning-based FMEA, resilience strategies, root cause analysis.
10	Agile-LSS Integration for Adaptive Execution	Combines Lean Six Sigma with Agile for flexibility, speed, and responsiveness.	Agile-LSS synergy, iterative development, continuous refinement.

4.3. DMAIC framework of Strategic Lean Leadership in LSS projects

The Define, Measure, Analyze, Improve, and Control (DMAIC) framework is a critical methodology in Lean Six Sigma (LSS), offering a structured, data-driven approach to process optimization. Within the context of Strategic Lean Leadership, DMAIC extends beyond simple process improvements by incorporating leadership-driven decision-making, workforce engagement, and alignment with strategic business objectives, promoting sustainable manufacturing excellence. **Table 8** highlights how Strategic Lean Leadership enhances each phase of the DMAIC cycle, driving efficiency, quality, and continuous improvement in LSS projects.

1) Define Phase: Establishing a Strategic Vision and Project Scope: The Define phase sets the foundation for Lean Six Sigma projects by ensuring alignment with overarching business strategy. It eliminates ambiguity by clearly outlining the project scope, objectives, and key stakeholder roles. The Project Charter defines critical components such as the problem statement, scope, and success criteria. By focusing on Critical-to-Quality (CTQ) factors, the project ensures it delivers customer-centric value, while the SIPOC analysis helps map workflows and stakeholder interactions. This structured approach ensures clarity, alignment, and a strong execution strategy.
2) Measure Phase: Establishing Performance Baselines with Data-Driven Insights: In the Measure phase, data is collected and analyzed to establish baseline metrics, laying the foundation for informed decision-making. Key Performance Indicators (KPIs) are defined to track project efficiency and effectiveness. Value Stream Mapping (VSM) identifies process bottlenecks and inefficiencies, while Failure Modes and Effects Analysis (FMEA) uncovers potential risks. These tools provide data-driven insights that pinpoint specific areas in need of improvement, guiding the team toward optimal performance.
3) Analyze Phase: Identifying Root Causes of Inefficiencies and Risks: The Analyze phase emphasizes diagnosing the root causes of inefficiencies and defects to prevent teams from addressing only superficial issues. Techniques like Root Cause Analysis (RCA), 5 Whys, and Fishbone Diagrams help identify performance gaps. Pareto Analysis ensures that high-impact issues are addressed first, while Regression Analysis and Hypothesis Testing validate potential improvements by evaluating process variability. These analytical methods strengthen risk management and form the foundation for process optimization.
4) Improve Phase: Implementing Targeted Solutions for Sustainable Efficiency: The Improve phase focuses on designing and implementing targeted solutions to enhance efficiency and performance. Lean methodologies, such as 5S (Sort, Set in Order, Shine, Standardize, Sustain), improve organization and eliminate waste. Tools like Kanban and Just-in-Time (JIT) systems streamline workflows, reduce lead times, and enhance operational flexibility. Before full-scale implementation, pilot testing and simulations validate improvements, minimizing risks and ensuring sustainable gains. This approach accelerates agility, improves productivity, and ensures long-term operational efficiency.
5) Control Phase: Ensuring Long-Term Success and Continuous Improvement: The Control phase ensures that improvements are not only maintained but continuously optimized. Standard Operating Procedures (SOPs) are put in place to standardize best practices and ensure consistency. Control charts and real-time dashboards provide ongoing monitoring, enabling teams to detect performance deviations and take corrective action swiftly. Regular audits, ongoing employee training, and robust feedback mechanisms promote a culture of continuous improvement, safeguarding against the regression of gains. This phase ensures that Lean Six Sigma benefits are sustainable over time.

In conclusion, The Strategic Lean Leadership-driven DMAIC framework enhances Lean Six Sigma project success by integrating structured problem-solving with leadership-guided decision-making and continuous improvement. By combining

data-driven insights with proactive leadership strategies, organizations can achieve sustainable manufacturing excellence, improved performance, and long-lasting operational gains. This comprehensive approach ensures that LSS initiatives address both immediate process challenges and long-term organizational goals, fostering continuous innovation and maintaining a competitive edge in the manufacturing sector.

Table 8. DMAIC framework of Strategic Lean Leadership in LSS projects.

#	Phase	Objective	Key Activities	Project Benefits
1	Define	Establish a clear strategic vision and project scope.	- Develop Project Charter and define Critical-to-Quality (CTQ) factors - Conduct SIPOC (Suppliers, Inputs, Process, Outputs, Customers) analysis - Align project goals with business strategy	- Clear objectives and stakeholder alignment - Minimized ambiguity and scope creep
2	Measure	Establish performance baselines through data-driven benchmarks.	- Define Key Performance Indicators (KPIs) and metrics - Apply Value Stream Mapping (VSM) to identify inefficiencies - Conduct Failure Modes and Effects Analysis (FMEA) for risk assessment	- Fact-based decision-making - Early detection of process inefficiencies
3	Analyze	Identify root causes of inefficiencies and risks.	- Conduct Root Cause Analysis (RCA), 5 Whys, and Fishbone Diagrams - Use Pareto Analysis to prioritize high-impact issues - Apply Regression Analysis and Hypothesis Testing for variability assessment	- Targeted problem-solving - Enhanced risk mitigation
4	Improve	Implement data-driven solutions for efficiency and quality.	- Apply Lean tools such as 5S, Kanban, and Just-in-Time (JIT) - Conduct pilot tests and simulations to validate improvements - Leverage automation and digital transformation	- Optimized workflows and waste reduction - Increased project agility and responsiveness
5	Control	Sustain improvements and ensure long-term project excellence.	- Implement Standard Operating Procedures (SOPs) and real-time monitoring systems - Use Control Charts and digital dashboards for process tracking - Conduct regular audits, feedback loops, and leadership training	- Ensures stability and continuous improvement - Strengthens governance and compliance

4.4. KPIs of Strategic Lean Leadership in LSS projects

Key Performance Indicators (KPIs) are essential for evaluating the success of Lean Six Sigma (LSS) initiatives. These metrics focus on process improvement, waste reduction, quality enhancement, and overall project performance. **Table 9** highlights a comprehensive set of KPIs designed to measure the success of LSS projects. Each KPI aims to improve project performance, streamline processes, reduce waste, and boost efficiency. Below is an in-depth explanation of each KPI:

1) Project Cycle Time: This KPI measures the time from project initiation to completion. Its goal is to reduce the overall project duration by identifying bottlenecks and inefficiencies. Reducing cycle time leads to faster delivery, improved productivity, and better time management.
2) Cost Savings: This KPI tracks the savings achieved through process improvements, waste reduction, and efficient resource utilization. It quantifies the financial benefits of Lean Six Sigma efforts, demonstrating how these initiatives contribute to cost control and providing a clear justification for further investment.
3) Defect Rate: The defect rate measures the frequency of defects during project execution or in the final deliverables. A low defect rate indicates that the project

is consistently producing high-quality results, leading to reduced rework, fewer errors, and higher customer satisfaction.

4) Customer Satisfaction (CSAT): CSAT measures how well the project meets customer expectations, typically through surveys or direct feedback. High customer satisfaction reflects that the project's outcomes align with client needs, fostering trust and loyalty while identifying areas for future improvement.
5) Process Efficiency: This KPI evaluates the efficiency of project processes against predefined standards. By identifying areas of inefficiency, this KPI drives continuous optimization, ultimately enhancing operational performance and overall project success.
6) Resource Utilization Rate: This KPI tracks the effectiveness of resource utilization, including human, financial, and material resources, throughout the project. Optimizing resource allocation minimizes waste, improves efficiency, and ensures that project goals are achieved with maximum effectiveness.
7) Risk Mitigation: Risk mitigation measures how effectively potential risks—such as delays, cost overruns, and resource shortages—are identified and managed. Effective risk mitigation ensures the project remains on schedule, within budget, and meets its predefined scope.
8) First Pass Yield (FPY): FPY measures the percentage of deliverables completed correctly the first time, without requiring rework. A high FPY rate reduces errors, waste, and rework, ultimately contributing to improved project efficiency and product quality.
9) On-time Delivery Rate: This KPI tracks the percentage of project milestones and deliverables completed according to schedule. Consistently meeting deadlines helps build customer trust, improves project performance, and ensures that overall project goals are met on time.
10) Lean Waste Reduction: This KPI is focused on reducing all forms of waste—time, materials, energy, etc.—within the project. By eliminating unnecessary steps and optimizing resource usage, it helps to boost productivity, reduce costs, and enhance overall efficiency.
11) Employee Engagement: This KPI measures the level of employee involvement in Lean Six Sigma initiatives and continuous improvement efforts. Engaged employees are more likely to contribute positively to the project, fostering a culture of collaboration, innovation, and shared ownership.
12) Sustainability Impact: This KPI evaluates the environmental and social impact of the project. It tracks factors such as carbon footprint, resource consumption, and waste generation. Incorporating sustainability ensures that projects align with corporate social responsibility goals, delivering positive environmental and social outcomes.

In conclusion, these KPIs are essential for assessing the success of Lean Six Sigma projects. They provide measurable benchmarks to evaluate process optimization, quality improvement, waste reduction, and risk management. By focusing on these KPIs, organizations can achieve timely, cost-effective, and sustainable results, ensuring that projects are aligned with both business objectives and customer expectations.

Table 9. KPIs of Strategic Lean Leadership in LSS projects.

#	KPI	Objective	Description	Project Benefits
1	Project Cycle Time	Streamline project duration for faster delivery.	Measures the total time taken from project initiation to completion.	Identifies delays and inefficiencies, accelerates delivery, and boosts productivity.
2	Cost Savings	Reduce operational costs through efficiency improvements.	Tracks reductions in project costs due to improved processes, waste reduction, and resource optimization.	Demonstrates financial benefits, justifies Lean Six Sigma investments, and enhances cost control.
3	Defect Rate	Minimize defects to improve process and product quality.	Measures the frequency of defects or errors during project execution or in the final output.	Improves process quality, reduces rework, and enhances customer satisfaction.
4	Customer Satisfaction (CSAT)	Align project outcomes with customer expectations for better results.	Assesses the satisfaction level of customers or stakeholders through surveys and feedback mechanisms.	Ensures alignment with customer needs, improves satisfaction, and identifies areas for improvement.
5	Process Efficiency	Enhance operational efficiency through process optimization.	Evaluates how efficiently processes are performed compared to expected or ideal standards.	Identifies process inefficiencies, promotes continuous optimization, and boosts overall performance.
6	Resource Utilization Rate	Maximize resource efficiency to improve productivity.	Measures the effectiveness of resource use (human, financial, material) throughout the project.	Optimizes resource allocation, reduces waste, and ensures project goals are achieved efficiently.
7	Risk Mitigation	Proactively address and manage potential risks throughout the project.	Tracks how effectively risks (e.g., delays, cost overruns) are identified and managed.	Minimizes risks, ensures projects stay on schedule, within scope, and on budget.
8	First Pass Yield (FPY)	Achieve high-quality results on the first attempt.	Measures the percentage of deliverables completed correctly the first time without the need for rework.	Enhances efficiency, reduces waste, and improves project quality by minimizing errors.
9	On-time Delivery Rate	Ensure timely completion of project deliverables and milestones.	Tracks the percentage of milestones and deliverables completed as scheduled.	Strengthens customer trust, ensures deadlines are met, and improves project performance.
10	Lean Waste Reduction	Eliminate waste in all forms (time, materials, energy) for efficiency.	Measures the reduction of waste through streamlined processes and resource optimization.	Increases productivity, lowers costs, and boosts overall operational efficiency.
11	Employee Engagement	Promote active participation in continuous improvement and Lean Six Sigma initiatives.	Measures the level of employee involvement and commitment to Lean Six Sigma activities.	Fosters a culture of collaboration, innovation, and shared ownership for success.
12	Sustainability Impact	Integrate sustainable practices into project management.	Measures the environmental and social impact of the project (e.g., carbon footprint, resource consumption).	Supports sustainability initiatives, reduces environmental impact, and aligns with corporate social responsibility goals.

4.5. Voice of Customer (VOC) analysis in LSS projects

Voice of Customer (VOC) analysis is a key element in Lean Six Sigma (LSS) projects, ensuring that customer expectations are captured and addressed systematically. As outlined in **Table 10**, focusing on core project dimensions—scope, schedule, quality, safety, and cost—enables organizations to align their LSS initiatives with customer needs, driving efficiency, quality, and overall satisfaction.

1) Scope Definition: A well-defined project scope is crucial for success, as customers expect clear, aligned deliverables. Inadequate scope definition can lead to scope creep, inefficiencies, and resource wastage. Tools like SIPOC (Suppliers, Inputs, Process, Outputs, Customers) and Quality Function Deployment (QFD) help translate customer needs into clear, actionable project goals, ensuring focus and alignment with business objectives.

2) On-time Delivery: Timely delivery is a top priority for customers, as delays can disrupt operations and increase costs. LSS tools such as Value Stream Mapping (VSM), Critical Path Method (CPM), and Just-in-Time (JIT) help eliminate bottlenecks and streamline workflows, reducing cycle times. Key performance indicators (KPIs) like on-time delivery rate and lead time reduction help track adherence to schedule.
3) Quality of Outputs: Customers demand high-quality results with minimal defects. Lean Six Sigma tools such as DMAIC (Define, Measure, Analyze, Improve, Control), Statistical Process Control (SPC), and Failure Mode and Effects Analysis (FMEA) help improve process reliability and product quality. By reducing defects per million opportunities (DPMO) and improving Sigma levels, organizations ensure consistent delivery of high-quality outputs.
4) Safety and Compliance: In regulated industries, safety and compliance are paramount. Customers expect zero incidents and full regulatory adherence. Tools like 5S (Sort, Set in Order, Shine, Standardize, Sustain), Root Cause Analysis (RCA), and Bowtie Analysis help identify and mitigate risks, promoting a safer work environment. Success is measured through reduced incident rates and improved compliance metrics.
5) Cost Optimization: Cost-effectiveness is crucial for customers, who seek solutions that deliver value without compromising quality. LSS tools such as Cost of Poor Quality (COPQ), Kaizen (Continuous Improvement), and Lean Waste Reduction (TIMWOOD—Transport, Inventory, Motion, Waiting, Overproduction, Over-processing, Defects) help eliminate inefficiencies, optimize resource utilization, and reduce costs. The result is measurable cost savings and improved return on investment (ROI).

In conclusion, VOC analysis ensures that LSS projects remain customer-centric, efficient, and high-quality, while addressing potential risks and inefficiencies. By managing scope, schedule, quality, safety, and cost systematically, organizations can consistently meet or exceed customer expectations, drive operational improvements, and achieve long-term success.

Table 10. Voice of Customer (VOC) analysis for LSS projects.

#	Project Dimension	Customer Requirements	Objectives	Key LSS Tools & Techniques	KPIs	Risk & Mitigation
1	Scope Definition	Clear deliverables & success criteria	Align scope with customer needs & minimize deviations	SIPOC, Kano Model, QFD (Quality Function Deployment)	Scope adherence %, Customer satisfaction	Risk: Scope creep Mitigation: Iterative planning, customer validation
2	Schedule Adherence	On-time project completion	Improve efficiency & eliminate delays	Value Stream Mapping (VSM), Critical Path Method (CPM), Just-in-Time (JIT)	On-time delivery %, Lead time reduction	Risk: Bottlenecks Mitigation: Lean workflow optimization
3	Quality Assurance	High-quality output, minimal defects	Reduce variation & enhance defect prevention	DMAIC, SPC (Statistical Process Control), FMEA (Failure Mode & Effects Analysis)	DPMO, Sigma level, First-pass yield (FPY)	Risk: Rework costs Mitigation: Six Sigma quality control

Table 10. (*Continued*).

#	Project Dimension	Customer Requirements	Objectives	Key LSS Tools & Techniques	KPIs	Risk & Mitigation
4	Safety & Compliance	Zero safety incidents, regulatory compliance	Foster a risk-aware culture & prevent hazards	5S, Root Cause Analysis (RCA), Bowtie Analysis	Incident rate, Compliance adherence	Risk: Safety hazards Mitigation: Regular audits, predictive analytics
5	Cost Optimization	Cost-effective solutions	Reduce waste & optimize resource use	COPQ (Cost of Poor Quality), Kaizen, Lean Waste Reduction (TIMWOOD)	Cost savings %, Waste reduction, ROI	Risk: Budget overruns Mitigation: Lean financial tracking

4.6. Integrating agile methodologies with LSS

Integrating Agile methodologies with Lean Six Sigma (LSS) provides a unique opportunity to enhance efficiency, responsiveness, and continuous improvement. Although both focus on performance optimization, their differing principles—Agile's flexibility and iterative approach versus LSS's structured, data-driven methodology—pose integration challenges. Successful integration requires addressing these challenges while capitalizing on the strengths of both frameworks. **Table 11** outlines the key challenges in Agile-LSS integration.

1) Cultural Misalignment: Agile encourages rapid decision-making, flexibility, and decentralized authority, while LSS emphasizes a more structured, data-driven approach. Achieving alignment requires leadership-driven cultural transformation that values both adaptability and rigorous process discipline.
2) Process Rigidity vs. Flexibility: LSS uses the DMAIC framework, which is structured and predictable, while Agile values adaptability to evolving requirements. A hybrid approach that incorporates iterative refinements within a disciplined process framework is necessary for success.
3) Metrics and Performance Measurement: Agile prioritizes customer-centric metrics like velocity and working software, while LSS relies on KPIs such as defect rates and process efficiency. Developing a unified system for performance measurement is essential to align both methodologies.
4) Role and Responsibility Conflicts: Agile uses self-organizing teams (e.g., Scrum Master, Product Owner), whereas LSS typically has a hierarchical structure (e.g., Green Belts, Black Belts). Clear role definitions within an integrated framework are vital to ensure collaboration and reduce redundancies.
5) Speed vs. Analytical Thoroughness: Agile favors rapid iterations and quick deployment, while LSS focuses on thorough data analysis before action. Balancing speed with careful analysis ensures decisions are both timely and well-informed.
6) Integration with Digital Tools: Agile is commonly applied in software development, while LSS originated in manufacturing. To apply LSS successfully in digital environments, organizations must leverage tools like automation, analytics, and AI-driven insights.
7) Stakeholder Alignment and Buy-in: Agile's decentralized decision-making contrasts with LSS's structured governance. Overcoming this requires transparent communication and strong executive support to align stakeholders across the organization.

8) Training and Skill Gaps: Agile practitioners may lack expertise in statistical analysis, while LSS experts might be unfamiliar with Agile workflows. Cross-training initiatives can help bridge these gaps and foster collaboration between teams.
9) Resistance to Change: Employees may resist a hybrid Agile-LSS approach due to unfamiliarity or perceived complexity. To mitigate resistance, organizations should implement change management strategies and pilot programs to ease adoption.
10) Scalability Across Teams and Functions: Agile works best in small, autonomous teams, whereas LSS is applied at the enterprise level. To scale Agile in larger organizations, it's important to adapt practices to suit different team sizes and organizational structures.
11) Data-Driven vs. Customer-Centric Approaches: LSS relies on process optimization through data analysis, while Agile focuses on customer feedback and quick iteration. A well-integrated approach should balance operational excellence with responsiveness to customer needs.
12) Short-Term vs. Long-Term Focus: Agile delivers quick, incremental results, whereas LSS aims for sustainable, long-term improvements. Aligning both approaches ensures that short-term successes don't undermine long-term stability and growth.
13) Compliance and Regulatory Constraints: Agile's iterative approach may conflict with regulatory requirements in some industries, while LSS ensures compliance through structured governance. Integrating compliance checkpoints within Agile workflows can address these concerns.
14) Innovation vs. Standardization: Agile thrives on innovation and experimentation, while LSS emphasizes consistency and process standardization. A successful integration should foster innovation while maintaining discipline and stability in core processes.
15) Sustaining Continuous Improvement: Agile's iterative improvements may not be sustained without reinforcement, while LSS ensures continuous long-term improvements. Institutions should embed mechanisms to sustain Agile-driven changes and reinforce continuous improvement.

In conclusion, the successful integration of Agile and Lean Six Sigma requires a strategic approach that blends rapid adaptability with data-driven rigor. By addressing key challenges such as cultural alignment, role clarity, and performance measurement, organizations can leverage both methodologies to enhance operational efficiency and responsiveness. Combining Agile's flexibility with LSS's process excellence empowers organizations to drive sustainable growth and maintain a competitive edge in today's fast-paced, ever-evolving business environment.

Table 11. Challenges and strategies for integrating agile methodologies with LSS.

#	Challenge	Description	Strategic Solution
1	Cultural Misalignment	Agile promotes flexibility, while LSS emphasizes structure, leading to resistance.	Foster leadership alignment, encourage a hybrid mindset and promote collaboration.
2	Process Rigidity vs. Adaptability	LSS follows a structured DMAIC cycle, while Agile focuses on iterative progress.	Develop a framework balancing Agile flexibility with LSS structure for seamless execution.
3	Metrics Misalignment	LSS prioritizes statistical validation, whereas Agile values speed and feedback.	Define unified KPIs blending Agile responsiveness with LSS process optimization.
4	Role Conflicts	Agile roles (Scrum Master, Product Owner) contrast with LSS's structured Belt hierarchy.	Clarify responsibilities and establish cross-functional collaboration.
5	Speed vs. Thoroughness	Agile promotes rapid iterations, while LSS requires data-driven analysis before changes.	Synchronize Agile sprints with LSS validation to balance speed with accuracy.
6	Digital Integration	Agile is widely used in software, whereas LSS originated in manufacturing.	Utilize AI, IoT, and predictive analytics to integrate Agile and LSS across digital and physical operations.
7	Stakeholder Resistance	Agile supports decentralized decision-making, while LSS follows structured governance.	Align Agile roadmaps with LSS-driven process controls to secure buy-in.
8	Skill Gaps	Agile teams may lack statistical expertise, while LSS practitioners may not be familiar with Agile workflows.	Implement cross-training programs to develop hybrid expertise.
9	Resistance to Change	Employees accustomed to either Agile or LSS may resist a hybrid approach.	Apply Lean Change Management and pilot hybrid initiatives.
10	Scalability Challenges	Agile is suited for small teams, while LSS is often implemented at an enterprise level.	Integrate Agile-at-scale frameworks (e.g., SAFe) with LSS principles for enterprise-wide alignment.
11	Customer vs. Data Focus	Agile prioritizes direct customer feedback, while LSS relies on data-driven decisions.	Balance Agile's customer-centricity with LSS's process-driven optimization.
12	Short- vs. Long-Term Goals	Agile focuses on quick wins, while LSS ensures sustainable improvements.	Align Agile's short-term gains with LSS's long-term stability.
13	Regulatory Compliance	Agile's flexibility can create challenges in regulated environments where LSS enforces structured compliance.	Integrate compliance checks into Agile sprints and align with LSS control phases.
14	Innovation vs. Standardization	Agile fosters rapid innovation, while LSS prioritizes process standardization.	Enable structured experimentation within LSS-defined parameters.
15	Sustaining Improvements	Agile supports continuous evolution, while LSS ensures stability.	Embed Agile retrospectives into LSS control mechanisms for sustained progress.

5. Conclusion and future work

This study examines how the integration of Lean, Six Sigma, and Total Quality Management (TQM) enhances leadership strategies for driving organizational transformation. It underscores the pivotal role of leadership in fostering collaboration, optimizing resources, and cultivating a culture of continuous improvement, which strengthens business agility, resilience, and responsiveness. The study introduces the Structured Lean Leadership Framework, aimed at developing the leadership capabilities essential for effective Lean Six Sigma (LSS) implementation and overcoming challenges like weak leadership commitment, resistance to change, and communication barriers. By aligning LSS with business objectives, customer needs, and sustainability goals through tools like DMAIC, KPIs, and VOC analysis, the research also explores the potential of combining LSS with Agile methodologies to improve operational efficiency, governance, and innovation. The findings provide key insights into leadership development and data-driven decision-making.

Future research should validate the leadership framework, investigate Agile-LSS integration in regulated industries, and explore the impact of Industry 4.0 technologies on LSS, leadership effectiveness, sustainability, and the role of digital transformation and organizational culture.

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