EPJ Web of Conferences **376**, 02002 (2026) https://doi.org/10.1051/epjconf/202637602002
ICRAMEN 2026

Integrated Lean and Green Management for Sustainable Organizational Performance: A Review

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Abstract. The coexistence of operational efficiency and environmental responsibility has led scholars and practitioners to study the integration of lean manufacturing and green management. By combining these methodologies organizations' can reduce their environmental impact while at the same time streamline production. This paper conducts a systematic review of 98 peer-reviewed studies published from 2005 to 2024 that examined the relationship between lean thinking, green practices, and sustainable organizational performance. The integrative conceptual model of lean-green integration has been developed based on the resource-based view (RBV) theory, natural-resource-based view (NRBV) theory, and the dynamic-capabilities theory. In our synthesis four integration patterns has been identified viz. sequential adoption, parallel deployment, hybrid embedding and systemic co-evolution. Evidence consistently points to significant improvements in economic, environmental and social performance metrics for companies that achieve deep synergistic integration. Critical enablers are top-management commitment, cross-functional collaboration, supply-chain alignment, and digital infrastructure However, siloed implementation, lack of resources in Small and Medium Enterprises (SMEs) and inconsistent measurement frameworks are identified as persistent impediments. The review identified important research gaps regarding longitudinal assessments, industry-specific studies, and the new technologies in improving lean-green synergies. The findings provide an actionable guidance for practitioners, researchers, and policymakers while establishing a solid theoretical foundation for future empirical studies.

1 Introduction

The intensification of global competition coupled with growing societal expectations around ecological stewardship has placed organisations under unprecedented pressure to deliver superior performance on multiple and frequently competing dimensions. Lean

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manufacturing, rooted in the Toyota Production System (TPS), has for decades constituted a cornerstone of operational excellence by systematically eliminating non-value-adding activities and compressing cycle times [1]. At the same time, green management practices such as environmental strategy, eco-innovation, and life-cycle thinking are becoming more important in industries. Earlier, industries adopted these practices mainly to follow environmental regulations. Now, companies are using green practices to improve sustainability, reduce waste, and gain competitive advantage in the market [4]. This raises an important question: can lean and green management practices be combined into one integrated system? Such kind of integration may help organizations improve sustainable performance more effectively than using lean or green practices separately. Early practitioner observations noted obvious structural parallels between lean and green: both target waste reduction, both emphasise process discipline, and both require systemic cultural transformation [5]. Yet the conceptual relationship between the two frameworks is considerably more complex than simple analogy suggests. Lean tools such as value-stream mapping (VSM), just-in-time (JIT) production, and kaizen cycles can reduce material consumption and energy intensity as beneficial by-products of efficiency improvements; however, lean logic does not inherently direct attention toward emissions, biodiversity, or end-of-life product management [6]. In contrast, the investments in clean technologies or renewable energy may introduce process variability which can temporarily conflict with lean stability objectives [2].

Despite a rapidly growing body of empirical literature, the field remains fragmented across disciplinary silos, methodological traditions, and geographic contexts. Prior reviews have offered important partial contributions: Dües et al. [5] mapped conceptual overlaps; Garza-Reyes [6] examined lean-green tools; and Ciccullo et al. [12] extended the lens to supply chains. However, none has synthesised the full breadth of available evidence through a rigorous, replicable review protocol aligned with PRISMA guidelines [44], nor has any prior work developed a theoretically grounded integrative model that distinguishes antecedents, integration patterns, mediating mechanisms, and multi-dimensional performance outcomes. This paper addresses that gap through a systematic review of literature. The review is guided by four research questions: (RQ1) What theoretical frameworks have been applied to explain lean-green integration? (RQ2) What integration patterns have been identified in the literature? (RQ3) What are the major enablers and barriers to lean-green integration? (RQ4) How does lean-green integration affect economic, environmental, and social performance outcomes? The paper proceeds as follows. Section 2 presents the theoretical foundations. Section 3 describes the methodology. Sections 4 through 7 present and discuss findings for each research question. Section 8 proposes an integrative conceptual model. Section 9 discusses the research gaps and future directions and the Section 10 presents the conclusion.

2 Theoretical Foundations

2.1 Lean Manufacturing: Core Principles and Evolution

The lean manufacturing originated in the Japanese automobile industry. It was then subsequently disseminated to Westerns' through the work of Womack and Jones [1]. The framework rests on five foundational principles: precisely specify value as defined by the customer, identify the value stream for each product family, enable value to flow without interruption, let the customer pull value from the producer, and pursue perfection continuously. Operationally, these principles are enacted through an array of tools including VSM, the 5S methodology, total productive maintenance (TPM), single-minute exchange of die (SMED), poka-yoke, kanban, and standardised work [15]. The unifying logic is the relentless elimination of the seven classic forms of waste muda identified as overproduction, waiting, transportation, over-processing, inventory, motion, and defects [43].

Over the years, lean thinking has expanded beyond manufacturing industries. It is now used in healthcare, service industries, public administration, and software development. Now, lean is considered an organization-wide management approach rather than only a manufacturing improvement tool [16]. The introduction of lean supply chain management further extended the analytical boundary to encompass supplier relationships and inter-organisational process optimisation [42]. Recently, the researchers have examined the compatibility of lean with Industry 4.0 technologies. It suggests that the digital tools such as real-time sensor data and advanced analytics can enhance lean implementation fidelity also it reduces the expertise required for waste identification [36].

2.2 Green Management: From Compliance to Strategic Resource

Green management encompasses the deliberate integration of environmental considerations into organisational strategy, operations, procurement, product design, and stakeholder communication [3]. The theoretical motivation for voluntary environmental investment beyond regulatory compliance has been debated extensively. Porter and van der Linde [4] challenged the dominant view that environmental regulation imposes unambiguous costs, arguing instead that stringent but well-designed environmental standards can stimulate innovation and ultimately enhance competitive position the celebrated Porter Hypothesis. Subsequent empirical work has produced mixed results, with the meta-analysis by Ambec et al. [22] concluding that the innovation-offsetting effect is real but industry- and instrument-specific.

Within the operations management literature, green practices have been operationalised along several dimensions: green procurement and supplier development, green product design incorporating life-cycle assessment (LCA), green production and energy management, reverse logistics and closed-loop supply chains, and environmental management systems (EMS) such as ISO 14001 [13]. Green human resource management (GHRM) has emerged as an additional dimension, recognising that environmental performance depends not only on technical systems but on employee competencies, motivation, and organisational culture [20].

2.3 Natural-Resource-Based View and Dynamic Capabilities

The resource-based view (RBV) of the firm [18] provides the foundational logic for explaining why lean-green integration can generate sustained competitive advantage: rare, valuable, inimitable, and non-substitutable capabilities built through the co-development of lean and green routines are difficult for competitors to replicate. Stuart Hart's [17] natural-resource-based view (NRBV) extends the RBV framework by incorporating the natural environment as a binding constraint and identifying three strategic capabilities pollution prevention, product stewardship, and sustainable development that become progressively more complex and provide increasing levels of competitive advantage. Lean-green integration maps naturally onto Hart's first capability, pollution prevention, which emphasises continuous improvement, waste minimisation, and process efficiency goals shared explicitly with lean thinking.

Dynamic capabilities theory [19] complements the NRBV by explaining how organisations sense environmental and market opportunities, seize them through reconfiguration of existing resources, and maintain competitive fitness over time. Lean-green integration demands exactly this kind of dynamic reconfiguration: firms must sense both efficiency opportunities and environmental risks, deploy blended tool sets, and continuously learn from feedback loops embedded in kaizen and environmental monitoring systems. Several scholars have argued that the routine co-deployment of lean and green tools constitutes a distinctive organisational capability referred to variously as 'lean-green capability' or 'eco-efficiency capability' that is path-dependent and accumulated through deliberate managerial investment [11].

3 Methodology

3.1 Review Protocol and Search Strategy

This study follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [44] to ensure transparency, reproducibility, and methodological rigour. Three electronic databases were searched: Web of Science (WoS), Scopus, and the Association of Business Schools (ABS)-listed journal portals. The search string combined Boolean operators across three conceptual clusters: (1) lean manufacturing OR lean production OR lean thinking OR lean management; (2) green management OR green manufacturing OR environmental management OR sustainable operations; and (3) performance OR sustainability OR competitive advantage. The initial search returned 1,847 records.

3.2 Inclusion and Exclusion Criteria

The (Table 1) indicate the detailing of Inclusion and Exclusion Criteria.
Studies were included:

- Published in peer-reviewed English-language journals ranked in the ABS list at two stars or above;
- Lean and green practices in combination or in relation to each other;
- Empirical results, case studies, or systematic conceptual models linking integration to performance outcomes; and
- Available in full text.

Studies were excluded because of followings:

- Lean or green in isolation, no integration: 187
- Grey literature / conference papers: 94
- Healthcare or public sector only: 68
- ABS rating < 2 stars: 53
- Non-English language: 27

Table 1. PRISMA 2020 Flowchart

Phase	Particular	Key Numbers
Identification	Database records (WoS, Scopus, ABS) + Other sources → Deduplication	1,847 + 55 → 1,590
Screening	Title/Abstract screening → Full-text retrieval	1,590 → 527 (excluded: 1,063)
Eligibility	Full-text assessment → Quality appraisal (CASP/MMAT) → Inter-rater reliability → Data extraction	527 → 98 (excluded: 429)
Included	Final synthesis	**n = 98**

4 Theoretical Frameworks in the Literature (RQ1)

Total of 98 papers are grouped into eight categories (Table 2) that addresses the convergence of Lean, environmental goals and digital tools. The most important category is Lean-Green Performance (41 papers) that offers empirical evidence regarding the operational and economic outcome. Additional notable clusters are comprising of Foundational Lean (14 papers), Lean-Green Integration (13 papers) and Green Supply Chain Management (13 papers). The remaining studies mostly concentrate on the Sustainable Operations (10), Social Sustainability/GHRM (7), Theoretical Frameworks (6) and Industry 4.0 or Circular Economy (6). The intersection of these categories underscores a deep relationship among digital innovation, social responsibility, and enduring industrial sustainability.

Table 2. Distribution of reviewed papers across identified research categories

Category	References covered
Category 1 : Foundational Lean Manufacturing	[1-8], [15-16], [34-35], [42-43]
Category 2: Theoretical Frameworks (NRBV, RBV, Dynamic Capabilities etc.)	[17-20], [38-39]
Category 3: Lean-Green Integration: Tools, Patterns & Frameworks	[9], [24-25], [29], [31-32], [45-48], [55-56], [87]
Category 4 : Green Supply Chain Management (GSCM)	[13-14], [21], [26], [27], [55], [58], [60-61], [64], [74-75], [80]
Category 5: Lean-Green Performance: Empirical Studies	[10-11], [23], [28], [30], [33], [50-54], [62-63], [63], [67-73], [76-83], [85-91], [93-97]
Category 6 : Systematic Reviews, Methodology & Sustainable Operations	[12], [22], [36], [37], [40-41], [44], [48], [56], [62]
Category 7 : Industry 4.0, Digital Technologies & Circular Economy	[36-37], [41], [82], [85], [89]
Category 8 : Social Sustainability, GHRM & Stakeholder Integration	[20], [38-39], [64], [92]

The reviewed corpus exhibits considerable theoretical heterogeneity. The NRBV [17] is the most frequently invoked framework (32% of studies), reflecting its natural alignment with both environmental management and capabilities-based competitive advantage. The RBV [18] appears in 24% of studies, often in conjunction with NRBV. Institutional theory was used in 18% of the studies mainly in research on multinational supply chains where different regulations influence adoption decisions [39]. Stakeholder theory appeared in 14% of the studies and it highlights the customer demands, investor expectations and community pressure as important drivers of voluntary lean-green adoption [38].

Dynamic capabilities theory [19] was used in 11% of the studies and became more common after 2018 reflecting a growing focus on organizational learning and adaptation. Transaction cost economics appeared in a few supply chain studies related to green asset-specific investments. However, 27% of the studies had no clear theoretical foundation and mainly relied on empirical observations or practical suggestions. This weak theoretical development limits the growth of strong research knowledge in this area. It also shows that there is a need for more future research and theoretical studies [40].

5 Patterns of Lean-Green Integration (RQ2)

Thematic synthesis reveals four distinct integration patterns that recur across the literature, varying in the degree of intentionality, simultaneity, and systemic depth with which lean and green are combined.

5.1 Sequential Adoption

The most common pattern, documented in 38% of reviewed studies, involves organisations that first establish lean maturity and subsequently deploy green practices. The rationale is pragmatic: lean disciplines create stable, transparent processes from which environmental improvement projects can be launched with lower coordination overhead [7]. Studies of

Japanese automotive transplants in North America and European manufacturing clusters confirm that lean-mature facilities exhibit faster green certification cycles and lower implementation costs. However, sequential adoption can produce a sub-optimal equilibrium where green practices are grafted onto lean logic without genuine systemic integration, limiting scope to energy-efficiency and direct-material waste while neglecting product-level environmental impacts.

5.2 Parallel Deployment

Approximately 29% of studies document organisations that launch lean and green initiatives concurrently but through separate organisational units typically operations and sustainability departments respectively. Parallel deployment can accelerate capability development on both dimensions, but the absence of cross-functional integration frequently results in conflicting objectives, duplicated data collection, and missed synergies [8]. Resource contention is especially acute in SMEs, where managerial bandwidth and capital are scarce. Studies show that the implementation of lean and green practices in parallel without proper coordination can create poorer environmental outcomes than sequential adoption. This is mainly happening because of process inconsistencies that reduce the operational efficiency gains.

5.3 Hybrid Embedding

Hybrid embedding is identified in 22% of the studies that refers to the integration of environmental performance indicators into existing lean tools. Illustrative examples include: incorporating carbon dioxide equivalent (CO_2e) and water consumption metrics into VSM to create 'green value-stream mapping' (GVSM); adding energy intensity and waste-to-landfill targets to 5S audits; and embedding life-cycle assessment data into design-for-manufacturability reviews [9]. This pattern is associated with the highest levels of tool-level synergy and is particularly prevalent in large manufacturing firms with dedicated continuous-improvement infrastructures. The enriched tools maintain operational familiarity for shop-floor employees while extending the measurement scope to environmental externalities, thereby reducing resistance to green change management.

5.4 Systemic Co-evolution

The most advanced integration pattern that is identified in 11% of the studies treats lean and green practices as interconnected parts of a broader sustainability strategy. This integration is reflected in corporate goals, governance systems, incentive structures, supplier agreements, and product development processes. Systemic co-evolution is most commonly associated with firms pursuing circular economy models, in which lean-driven process efficiency is combined with green-driven material loop-closing to create self-reinforcing value cycles [41]. Studies of industry leaders such as Toyota, Interface, and Scania suggest that systemic co-evolution produces the strongest and most durable sustainability performance but requires decade-scale institutional investment and unwavering strategic commitment.

6 Enablers and Barriers to Lean-Green Integration (RQ3)

6.1 Enablers

Top management commitment emerges as the single most consistently identified enabler across the reviewed corpus (cited in 71% of studies). Visionary leadership that frames lean and green as complementary rather than competing priorities creates the organisational conditions resource allocation, tolerance for short-term disruption, and cultural signalling under which integration can flourish [10]. Several longitudinal case studies document clear inflection points where senior executive sponsorship catalysed integration velocity.

Cross-functional collaboration is the second most cited enabler (64% of studies). The successful integration requires collaboration among industrial engineers, environmental managers, procurement specialists, and supply chain analysts. Studies show that cross-functional lean-green teams, shared KPI dashboards and joint kaizen-environmental review activities improve integration outcomes [11]. Supply-chain alignment extending lean and green disciplines to first- and second-tier suppliers is identified in 58% of studies as essential for achieving scope-3 environmental impact reductions while maintaining material flow efficiency. Digital infrastructure, including enterprise resource planning (ERP) systems enhanced with environmental modules, IoT-enabled energy monitoring, and advanced analytics platforms, is identified in 41% of post-2015 studies as an increasingly critical enabler, consistent with the Industry 4.0 literature [37].

6.2 Barriers

Resource constraints in SMEs represent the most frequently cited barrier (mentioned in 55% of studies). Unlike large multinational companies that can invest in both lean and green capability development, SMEs often face the serious limitations in capital, skills, and management time, making simultaneous adoption difficult. The silo-based organizational structures where the environmental responsibilities remain separated from operations management; also, it limits the integration of lean and green practices. Many firms focus on mainly on short-term financial performance and overlook long-term sustainability benefits. This was identified as a major cognitive and structural barrier in 47% of the reviewed studies, especially in publicly listed companies facing quarterly performance pressure.

Measurement inconsistency is both a practical and research-related challenge. The lack of standardized metrics for measuring the lean-green synergies makes it difficult for the managers to justify implementation and for researchers to compare the findings across studies [6]. This challenge becomes more complex because of the sustainable performance includes economic, environmental, and social dimensions, which are often measured using different methods. Many studies also identified cultural resistance to change as a major barrier, especially among the middle-management and shop-floor employees who view green practices as an additional workload. This issue requires effective change-management strategies to overcome.

7 Performance Outcomes of Lean-Green Integration (RQ4)

7.1 Economic Performance

The reviewed literature shows that lean-green integration generates positive economic performance outcomes comparing with the lean or green implementation in isolation. Cost reduction is the most robustly documented outcome: energy and material cost savings arising from the elimination of eco-inefficiencies compound lean-driven direct-cost reductions, producing multiplicative rather than additive economic benefits [7]. Studies employing quantitative methods including regression analysis on plant-level panel data and structured equation modelling (SEM) on survey samples report that lean-green integrated firms achieve 15-28% lower production costs and 12-22% higher return on assets compared to non-

integrated firms, though these estimates must be interpreted cautiously given selection-bias risks in observational designs.
Revenue enhancement through differentiated market positioning is identified in 44% of studies. Eco-efficiency credentials and sustainability certifications increasingly serve as procurement prerequisites in business-to-business markets and as trust signals in consumer markets, particularly in Europe and Japan [13]. Innovation outcomes new product development, process patents, and green technology licensing are reported in 31% of studies, consistent with the Porter Hypothesis and with NRBV propositions regarding the competitive value of proactive sustainability strategy.

7.2 Environmental Performance

Environmental performance improvements are, predictably, most comprehensively documented in studies explicitly designed to measure them. Waste-to-landfill reduction, energy intensity improvement, water consumption reduction, and greenhouse gas emission abatement are the most commonly reported metrics. The hybrid-embedding and systemic co-evolution integration patterns are associated with the largest environmental improvements, as these patterns extend the environmental scope beyond direct production emissions to encompass supply-chain and product-use-phase impacts [9]. Several studies document that lean-green integrated firms achieve ISO 14001 certification at lower cost and with faster cycle times, and that certified firms subsequently outperform non-certified peers on independently verified environmental metrics [21].
A nuanced finding emerging from 19% of studies concerns potential environmental trade-offs within lean logic: the JIT principle of small, frequent deliveries can increase transport frequency and thus logistics-related emissions even as production emissions fall, a phenomenon termed the 'lean paradox' by several authors [35]. Addressing this paradox typically requires supply-chain redesign milk-run logistics consolidation, local sourcing strategies, or modal shift to lower-emission transport modes reinforcing the argument that genuine lean-green integration must encompass the full supply chain rather than individual production facilities.

7.3 Social Performance

Social performance encompassing employee wellbeing, occupational health and safety, community impact, and labour practice quality receives comparatively less attention in the lean-green integration literature, reflecting broader gaps in the sustainable operations management field [11]. Available evidence nonetheless indicates that lean-green integrated workplaces report lower occupational injury rates (attributed to 5S discipline and ergonomic improvements), higher employee engagement scores (attributed to involvement in kaizen and environmental improvement events), and stronger labour retention. Community and reputational benefits are documented qualitatively in several in-depth case studies of firms in environmentally sensitive industries. The social dimension of lean-green integration represents a significant research opportunity, particularly in the context of the United Nations Sustainable Development Goals (SDGs), which position social equity as co-equal with economic and environmental sustainability.

8 An Integrative Conceptual Model

Synthesising the theoretical and empirical insights developed in Sections 4 through 7, we propose an integrative conceptual model of lean-green integration for sustainable organisational performance. The model is structured around four interconnected layers: contextual antecedents, integration enablers, integration patterns, and multi-dimensional performance outcomes, with feedback loops representing learning and adaptation mechanisms.

At the antecedent layer, the model identifies three sets of drivers (Table 3). External pressures including regulatory requirements, competitive dynamics and stakeholder demands create the imperative action. Internal resources include lean maturity, green capabilities, digital infrastructure, and human capital these determine the organisation's capacity to integrate. Strategic orientation, encompassing top management commitment and long-term sustainability ambition, mediates the translation of external pressures and internal resources into deliberate integration investment.

Table 3. Drivers of Antecedent layer

Drivers	Components
External Pressures	Regulatory mandates, customer green demands, competitive dynamics, stakeholder pressure
Internal Resources	Lean maturity, green capability, digital infrastructure, human capital
Strategic Orientation	Top management commitment, sustainability vision, governance alignment, culture

At the integration-enabler layer, cross-functional structures, shared performance measurement frameworks, supply-chain alignment mechanisms, and learning systems (kaizen events, environmental audits) operate as the organisational scaffolding through which lean and green capabilities are combined. The specific integration pattern (Table 4) that emerges sequential, parallel, hybrid, or co-evolutionary depends on the maturity of these enablers, the severity of resource constraints, and the strategic scope of the integration agenda.

Table 4. Lean-Green Integration Patterns

Integration Pattern	Studies	Definition & Core Characteristics	Theoretical Foundation	Supporting References
Sequential Adoption	38% n = 37	Organizations should first implement lean before systematically deploying green practices. Lean process and waste-elimination culture can create the managerial readiness needed for the environmental management adoption.	Natural Resource-Based View (NRBV) [17]; Resource-Based View (RBV) [18]; Institutional Theory [39]	[2], [10], [21], [25], [27], [46], [48], [49], [54], [58], [59], [60], [63], [64], [65], [68], [72], [75], [76], [77], [79], [88]
Parallel Deployment	29% n = 28	Lean and green are implemented simultaneously but managed separately. This approach accelerates the capability development but may create conflict and duplicate data collection.	Institutional Theory [39]; Stakeholder Theory [38]	[3], [7], [8], [11], [12], [13], [14], [20], [21], [26], [51], [52], [55], [56], [59], [64], [69], [80], [82], [83]
Hybrid Embedding	22% n = 22	Existing lean tools are upgraded with environmental performance indicators that creates integrated approaches like Green Value Stream Mapping (GVSM), Sustainable VSM (Sus-VSM), Eco-	Dynamic Capabilities Theory [19]; NRBV [17]; Triple Bottom Line	[6], [9], [24], [29], [31], [32], [33], [45], [47], [53], [67], [73], [78], [82], [86], [87], [89], [91]

		5S, Eco-SMED and Lean Six Sigma-Green DMAIC. This pattern extends the traditional lean metrics to include CO_2 emissions, energy consumption, water usage, and material-flow costs.	(TBL) Concept	
Systemic Co-evolution	11% n = 11	Lean and green practices are developing together as part of a broader sustainability strategy. Organizations are integrating these practices into governance systems, supplier management, product development and organizational culture. This approach also supports Circular Economy principles and Sustainable Development Goals (SDGs). As a result, industries can achieve better economic, environmental, and social performance in the long term.	Dynamic Capabilities Theory [19]; NRBV [17]; Stakeholder Theory [38]	[11], [29], [41], [60], [62], [82], [90], [91], [92]

At the performance-outcomes layer, the model posits that synergistic integration particularly hybrid embedding and systemic co-evolution produces outcomes across all three pillars of sustainability that are quantitatively and qualitatively superior to those achievable through isolated lean or green programmes. Feedback loops from performance measurement to strategic orientation and capability investment ensure dynamic reconfiguration over time, consistent with Teece et al.'s framework [19].

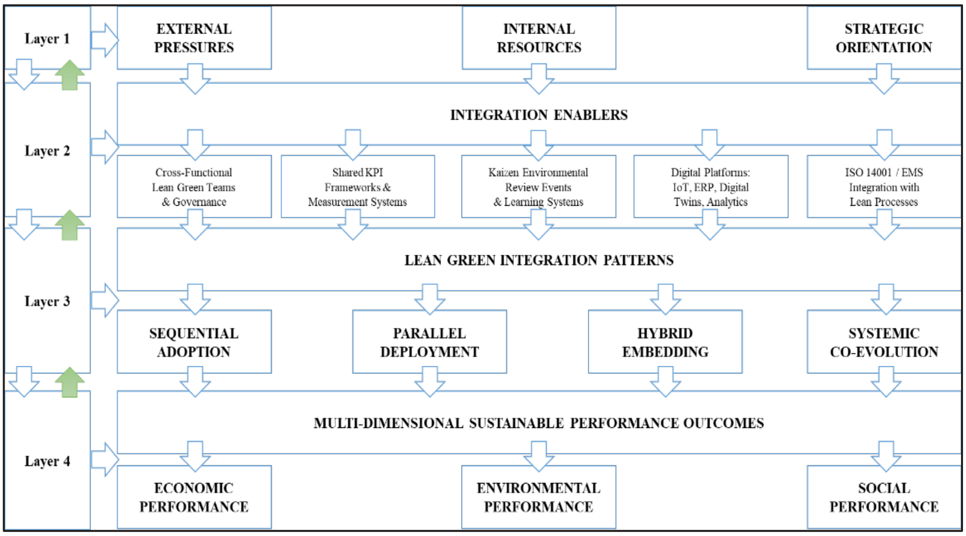

Fig.1. Integrative Conceptual Model

The model (Fig.1) thus positions lean-green integration not as a one-time programme but as an ongoing organisational learning process that deepens in sophistication as capabilities accumulate.

9 Research Gaps and Future Research Directions

There are several important research gaps that need to be explored in future. First, the overwhelming majority of reviewed studies employ cross-sectional designs that capture a single point in the integration trajectory, making causal inference difficult and obscuring the dynamic accumulation of lean-green capabilities over time. Longitudinal research designs panel data analyses covering at least five years, or longitudinal qualitative case studies employing process tracing are urgently needed to establish causal mechanisms and temporal patterns [40].

Second, the boundary conditions of lean-green integration require systematic examination. Most empirical evidence derives from large manufacturing firms in Japan, Germany, and the United States; the applicability of findings to SMEs, service industries, and firms in emerging economies where institutional environments, technological endowments, and competitive pressures differ substantially remains under-examined. Industry-comparative studies employing matched-sample designs could substantially advance boundary-condition knowledge [14].

Thirdly, the intersection of lean-green integration with emerging technologies is a frontier of great theoretical and practical significance. Industry 4.0 technologies, the Industrial Internet of Things (IIoT), artificial intelligence-driven process optimisation, digital twins and blockchain-enabled supply-chain transparency can help overcome many of the measurement and coordination barriers to deep integration. Research exploring how digital technologies amplify lean-green synergies and what new capabilities they require is nascent but rapidly emerging [37]. Fourth, the social sustainability dimension of lean-green integration demands dedicated theoretical and empirical attention, particularly regarding employee experience, community impact, and human rights in global supply chains aligned with SDG frameworks.

10 Conclusion

The present systematic review analyzed 98 peer-reviewed studies for understanding the current state of lean-green integration for sustainable organizational performance. The results show that lean and green management practices are inherently compatible because both aims are to reduce waste and improve efficiency. But to be successful in integration, you need good organizational planning and investment, not just using similar tools. The review revealed four dominant patterns of integration: sequential adoption, parallel deployment, hybrid embedding, and systemic co-evolution. These patterns represent different stages, in which organizations can progressively reinforce the lean-green integration. The results also indicate that the deeper the integration the better the economic, environmental and social performance. The longest-term benefits are for those entities that succeed in hybrid embedding and systemic co-evolution. Key enablers are commitment from top management, cross-functional collaboration, supply-chain alignment, and digital infrastructure. Limited resources, silo-based organizational structures, short-term financial focus and lack of standard performance measurement systems are major barriers. The conceptual model proposed in this study can help researchers to conduct future empirical studies and help industries to identify integration gaps and improve sustainability practices. The integration of lean efficiency and green innovation is becoming an important source of competitive advantage and organizational growth as sustainability challenges continue to grow. Future research directions should include longitudinal studies, cross-industry analysis, and the role of advanced technologies in lean-green integration.

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